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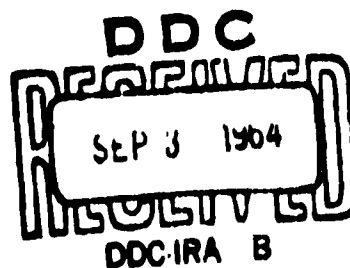
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A PROTOTYPE MANUAL
ON

CIVIL DEFENSE ASPECTS OF WATERWORKS OPERATIONS

CONTRACT NO. OCD-OS-62-106
SUBTASK NUMBER 3237A



AUGUST 1964

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**A PROTOTYPE MANUAL
ON
CIVIL DEFENSE ASPECTS OF WATERWORKS OPERATIONS**

**Prepared For
The Office of Civil Defense, Department of Defense
Under the Provisions of
Contract No. OCD-OS-62-106
Subtask Number 3237A**

**"This report has been reviewed in the Office of Civil Defense,
Office of the Secretary of the Army, and approved for publication."**

**Engineering-Science, Inc.
150 East Foothill Blvd.
Arcadia, California**

August 1964

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PREFACE

We as a nation have not ignored the problem of survival from nuclear attack. We of the waterworks industry, as a vital utility upon which depends the nation's life and health, must also not ignore that problem. Survival following a nuclear attack has been studied, and is being studied, by many experts. Some studies have indicated that initial casualties in the tens of millions could occur from an attack on the United States. But these studies also show that as many as 50 million persons could be killed by nuclear radiation from fallout after having survived the initial blast and fire! There will be survivors after such an attack, but the number who survive and the length of time they would survive would depend upon preparations made before the attack. This, alone, is ample reason for us to plan and provide for civil defense.

Preparedness consists of determining that a problem exists; analyzing the problem to determine the relative risks of specific actions; and then developing plans, hardening facilities, acquiring or stockpiling resources of supplies and tools, and training people in survival knowledges and skills. Civil Defense consists of maintaining a state-of-readiness. Procedures and actions must be provided in advance of the possible need for their use. Obviously, there is no time to effectively do these things after the bomb falls.

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CHAPTER I
PURPOSE AND SCOPE OF MANUAL

This manual has been prepared with the following principal objectives:

1. To familiarize water utility and civil defense personnel with methods for survival and recovery in the event of a nuclear war.
2. To stimulate and assist water utilities in developing emergency plans to cope with a nuclear disaster.
3. To provide a procedural guide for restoration and for training personnel in postattack emergency repair procedures, recovery techniques, and safety measures.

The manual content is based upon available information and selected assumptions about the probable postattack condition of water utility systems and practical countermeasures which can be made available. Much of the emphasis is on radiological defense because waterworks personnel, in general, have some knowledge of how to cope with the other effects of nuclear warfare. However, the magnitude of these other effects, blast, fire, etc. resulting from a nuclear explosion, will be much greater than ever experienced heretofore, consequently, appropriate information is presented on physical protection of the water supply system.

The following chapters of this manual offer a guide to the development of civil defense plans for waterworks of any size, type and location. Each of the suggested ideas should be considered carefully, although some suggestions may not be applicable to particular situations. Sometimes, detailed technical information must be obtained elsewhere. In such cases the list of references provided at the end of each chapter in this manual will prove of value. Also, it is recommended that technical help be sought from local, state, and federal civil defense, public health, and other agencies.

The format of this manual has been prepared so that events and their corrective measures are presented in chronological order. Chapters II through VII takes the reader from "Nuclear Weapon Effects", "Vulnerability Assessment", "Protective Measures", "Postattack Assessment of Plant Operation", and "Recovery of Plant Operations" through "Emergency Sources and Supply Procedures". Chapter VIII, "Disaster Plan", provides guide lines which water utilities can use to incorporate the information presented in preceding chapters into an effective plan of operation. A disaster plan check list is also included.

Before reading Chapter II, "Nuclear Weapon Effects", it would be well to read Appendix A, the "Facts on Radiation and Fallout", unless previous study of nuclear radiation has been more than casual. There are many common misconceptions about radiation, especially radiation from fallout. It is important to understand the facts before reading further.

Appendix B is a glossary of civil defense and nuclear weapon terminology. The reader is urged to consult it freely.

Chapter II, which describes the effects of nuclear weapons, begins our study of radioactivity and civil defense. Information is presented in this chapter which will assist in understanding the over-all problems resulting from nuclear warfare. The gross effects of assumed nuclear detonations - blast, thermal radiation and nuclear radiation - may be predicted with reasonable certainty. It should be kept in mind that the amount of physical damage to a given community would depend upon a number of factors including its closeness to the target site, the size of the weapon delivered, and whether the bomb was exploded on the ground, water or high in the air. All cities and towns would not be directly at or under the explosion. Most cities and towns could be heavily affected by fallout, without being affected by blast and thermal radiation, from a series of bombs exploded on high-priority targets. Radiological defense therefore, requires special consideration by all water works wherever their location.

Chapter III will guide water utility operators and management in assessing the vulnerability of their own system and personnel to a nuclear attack. It is pointed out that vulnerability encompasses much more than structural considerations. Criteria are presented concerning the degree of vulnerability to blast, thermal and ionizing radiation effects and information is given on how to compute probable effects. Procedures for safely leaving shelters under radioactive conditions are given. The chapter concludes with a detailed example of an ideal assessment on a water utility illustrating possible system weaknesses and the companion corrective measures. The vulnerability assessment information is used to provide protective measures which will expedite recovery after an attack.

Chapter IV presents principles on protective measures that can be taken to protect personnel and facilities from nuclear explosions. Blast and thermal protection is discussed, but radiological protection from fallout is emphasized and the provision and use of shelters is stressed. Design criteria for fallout shelters and their operation is discussed. Specific measures for control of contamination and for decontamination are reviewed. The provision of these protective measures will enable the utility to more effectively initiate their operations after an attack.

Chapter V describes the conditions and necessary actions to be taken following a nuclear attack. Postattack damage reconnaissance and assessment procedures for water utility personnel are given so that functional plans, leading to restoration of operation, can be made and carried out in as rapid and safe a manner as possible. The need for adequate communications

is stressed. An assessment and evaluation will have to be made of the surviving facilities, equipment, personnel and community. Of special importance in a waterworks is the condition of the water supply, and procedures for detecting and assessing radioactivity in the water supply are given. The effects of fallout on restoration are discussed. The urgency or priority of certain actions as related to the need and hazards involved must be evaluated. The results of the assessment are used to determine the post-attack water needs; the facilities, equipment and personnel that can be used and the most effective methods and procedures to expedite operation of the water system.

Chapter VI presents methods and procedures for emergency repair, restoration and operation during the postattack recovery period. Initial emphasis is on organization, command and succession within the water utility; use of operation control centers; and coordination and liaison with civil defense authorities and other vital utilities. Fire control and debris removal as they relate to water utility structures are reviewed; radiological decontamination procedures are thoroughly covered; system repair considerations are discussed; quality standards and control during the recovery period are reviewed; and finally power considerations are covered. All of these activities are directed towards the supplying of emergency water to survivors.

Chapter VII deals with sources of water that are or can be made available during emergencies for various uses and needs and the procedures involved in supplying this water. Potential sources, many of which are overlooked, are reviewed and suggestions are made for inventorying these as to location and to their quantity, quality, and other consideration. This information can be used to make a rapid postattack appraisal of the water supply situation. Emergency water treatment methods, delivery systems, points of distribution and rationing are discussed.

Chapter VIII incorporates the information already presented in this manual into a proposed comprehensive disaster plan for survival and recovery following a nuclear attack. It enables each water utility to prepare a functional plan for their particular organization and circumstance. This chapter not only provides the means of preparing a plan but also attempts to stimulate self evaluation with the ultimate development of a plan followed by action, in the form of hardening of facilities and the initiation of training programs and drills to make the plan functional. The accompanying disaster plan check list will facilitate the development of procedures leading to an effective survival and recovery plan.

CHAPTER II

NUCLEAR WEAPON EFFECTS

INTRODUCTION

While the nature of nuclear explosions is a relatively complex subject, the gross effects of an assumed nuclear weapon detonation may be predicted with reasonable certainty. It is the purpose of this chapter to present information that will be helpful in understanding over-all problems associated with a nuclear weapon attack and then in subsequent chapters relate them to water utility facilities and personnel, and their functions.

CHARACTERISTICS OF NUCLEAR EXPLOSIONS

General Properties

Nuclear weapons are similar to those of more conventional types in so far as their destructive action is due mainly to blast or shock. On the other hand, there are several basic differences. First, nuclear explosions can be many thousands (or millions) of times more powerful than the largest conventional detonations. Second, much of the energy in a nuclear explosion is in the form of light and heat, generally referred to as "thermal radiation". Third, the nuclear explosion is accompanied by highly penetrating and harmful invisible rays, called "initial nuclear radiation". Finally, radioactive debris remaining after a nuclear explosion emit similar radiations over an extended period of time. This is known as "residual nuclear radiation" (Figure 1).

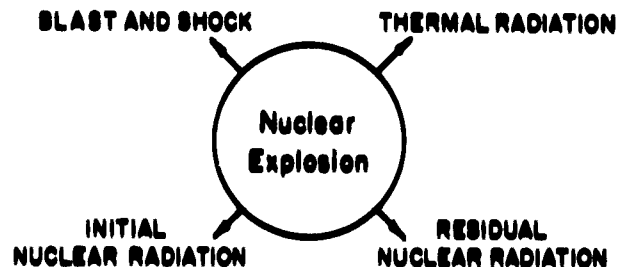


Figure 1.—EFFECTS OF A NUCLEAR EXPLOSION

Energy Yield of Nuclear Explosions

A nuclear weapon is usually described in terms of the total energy it can release in comparison to the number of tons of TNT required to release the same amount of energy when exploded. Thus, the detonation of a 1-megaton nuclear bomb releases the same amount of energy as the explosion of approximately 1 million tons of TNT. The earliest nuclear bomb, such as dropped over Japan in 1945, released roughly the same quantity of energy as 20,000 tons of TNT. Since that time, much more powerful weapons, with energy yields in the megaton range, have been developed.

The distribution of energy in nuclear explosions depends on the nature of the weapon and particularly on the environment of the explosion. Figure 2 shows the approximate distribution of energy that would occur for a detonation in the atmosphere.

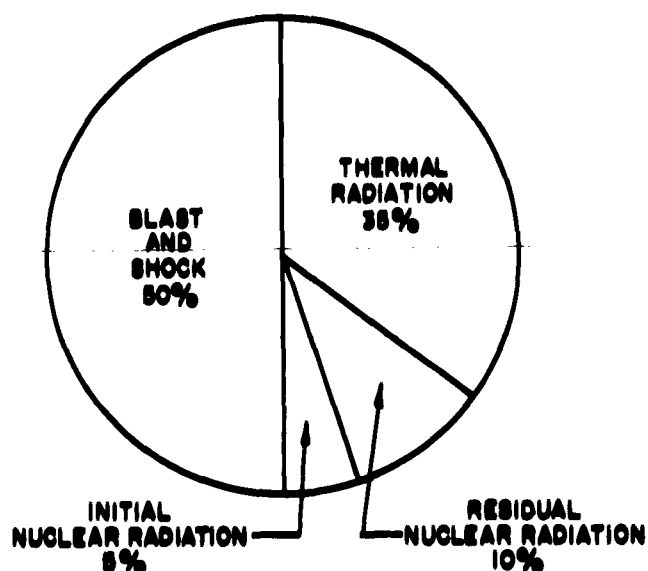
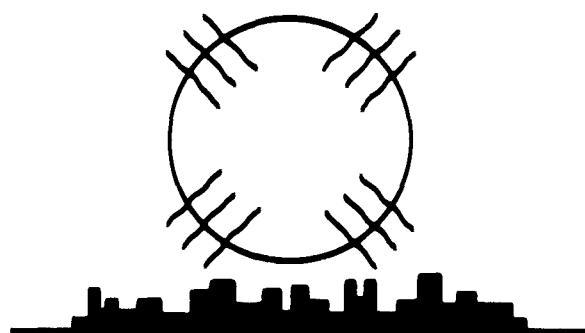


Figure 2.—DISTRIBUTION OF ENERGY IN A TYPICAL AIR BURST OF A WEAPON AT AN ALTITUDE BELOW 100,000 FEET

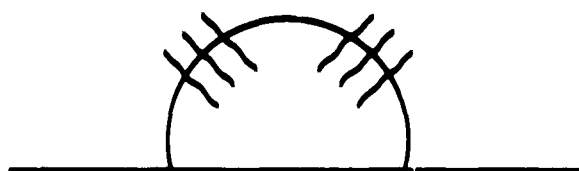
Types of Nuclear Explosions

The immediate phenomena associated with a nuclear explosion, as well as the effects of shock and blast, and thermal and nuclear radiations, vary with the location of the point of burst in relation to the surface of the earth. Figure 3 illustrates and describes the three principal types of burst.



Air burst

An air burst is defined as one in which the bomb is exploded in the air so high above land or water that the fireball (at maximum brilliance) does not touch the surface. Great blast and heat hazards are produced. The heat wave resulting from the explosion of a one-megaton nuclear weapon can cause moderately severe burns of exposed skin as far as 12 miles from the point of detonation. The warmth may be felt at a distance of 75 miles. Practically no early or close-in fallout¹ is produced.



Surface burst

In a surface burst, the ball of fire touches the ground. Because of its intense heat, large amounts of rock, soil, and other materials will be vaporized and will rise up into the cloud. An important difference between a surface burst and an air burst is that in the surface burst the atomic cloud is much more heavily loaded with this vaporized material; therefore, a surface burst causes much more early radioactive fallout than an air burst.



Subsurface burst

A subsurface burst is one in which the center of a nuclear explosion occurs under the ground or under water. Underground or underwater shock is produced, and according to the depth at which the explosion occurs, some of the shock will escape to produce air blast. Much of the heat wave and immediate nuclear radiation is absorbed within a short distance by the ground or water. However, large amounts of earth or water near the explosion will be contaminated with radioactive materials.

Figure 3— TYPES OF BURSTS

¹ Early fallout consists of the radioactive contaminated particles which return to the earth within 24 hours after a nuclear explosion.

In the event of a nuclear attack it is probable that the type of nuclear detonation most likely to be experienced will be a relatively low altitude air burst and/or surface burst. For simplification of discussion to follow in this chapter only the effects of these two types of burst are considered.

Chronological Development Of A Nuclear Explosion

The chronological development of a nuclear explosion on surface burst appears in Figure 4.

THERMAL RADIATION

General Properties

The fireball sends out thermal radiation in two pulses, making up approximately 35 percent of the bomb's total energy. The first pulse, a split-second ultraviolet flash, is not a major hazard. The second pulse, mostly infrared, lasts several seconds and carries nearly all the heat of the burst which radiates outward in essentially straight lines at the speed of light. As the heat radiates from the fireball, it spreads over even greater areas, so thermal radiation levels diminish sharply with distance (Figure 5).

Incendiary Effects

Because thermal radiation is applied only for a matter of seconds, light, easily kindled materials are most likely to ignite. Surveys show that typical American cities contain 5 to 25 points per acre where fires might begin from thermal radiation. More important, this readily ignited material can lead to the ignition of less combustible materials and result in a conflagration producing widespread damage.

Effects On Personnel

Thermal radiation can cause burn injuries either directly, i.e., by absorption of the radiant energy by the skin, or indirectly, as a result of fires started by the radiation. The direct burns are often called "flash burns", since they are produced by the flash of thermal radiation from the fireball. The indirect (or secondary) burns are referred to as "flame burns"; they are identical with skin burns that would accompany (or be caused by) any large fire no matter what its origin.

As a rule, all persons exposed to thermal radiation from a nuclear explosion within a range in which the energy received is sufficient to cause second-degree flash burns (at least) will be potential casualties. Figure 5 illustrates the relationship of weapon yield, rate of delivery of thermal energy, and distance, with expected degree of burns for exposed personnel.

Any solid opaque material, e.g., a wall, a hill, or a tree, between a given object and the fireball will act as a shield and provide some protection.

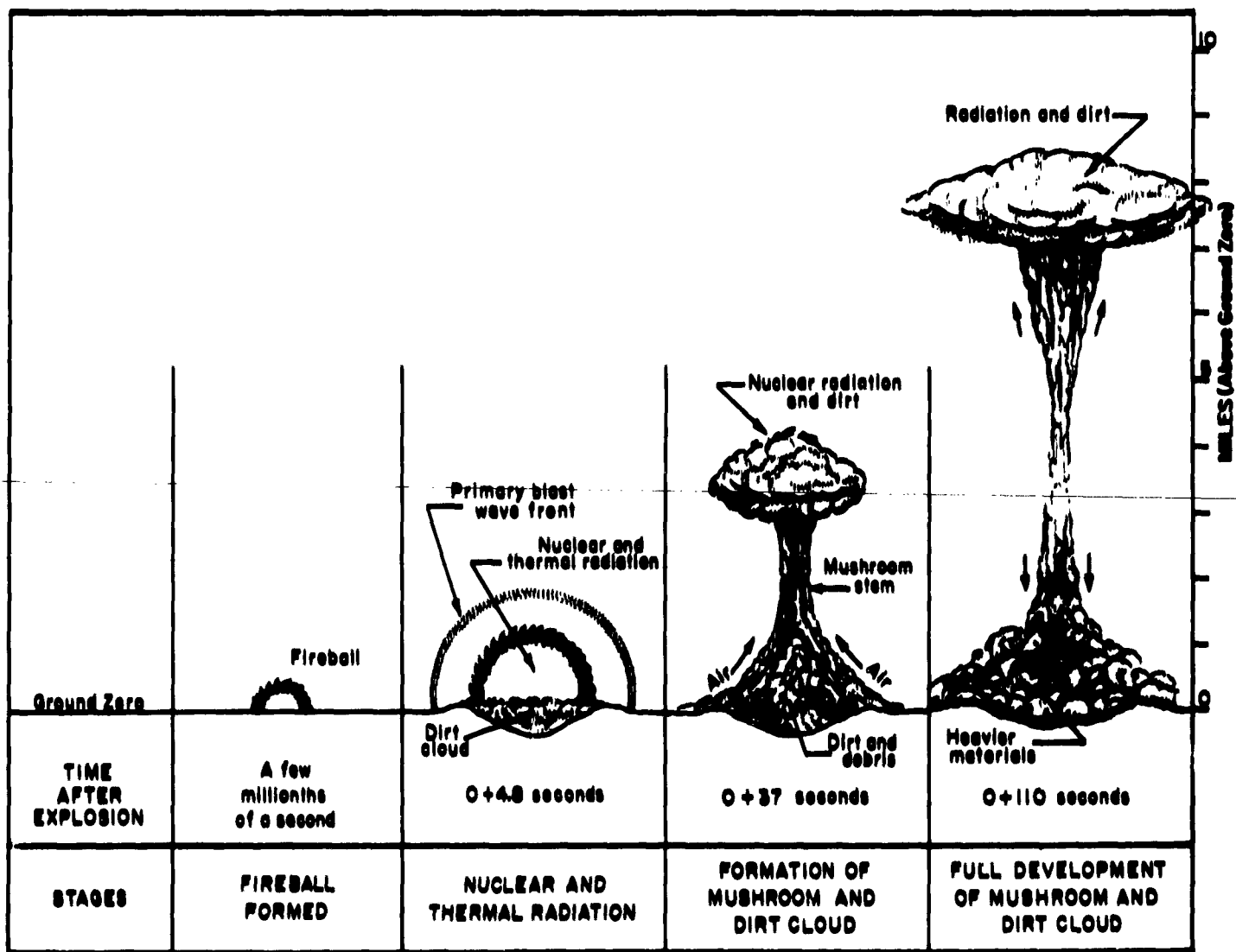


Figure 4.— STAGES OF A NUCLEAR SURFACE BURST (IMT)

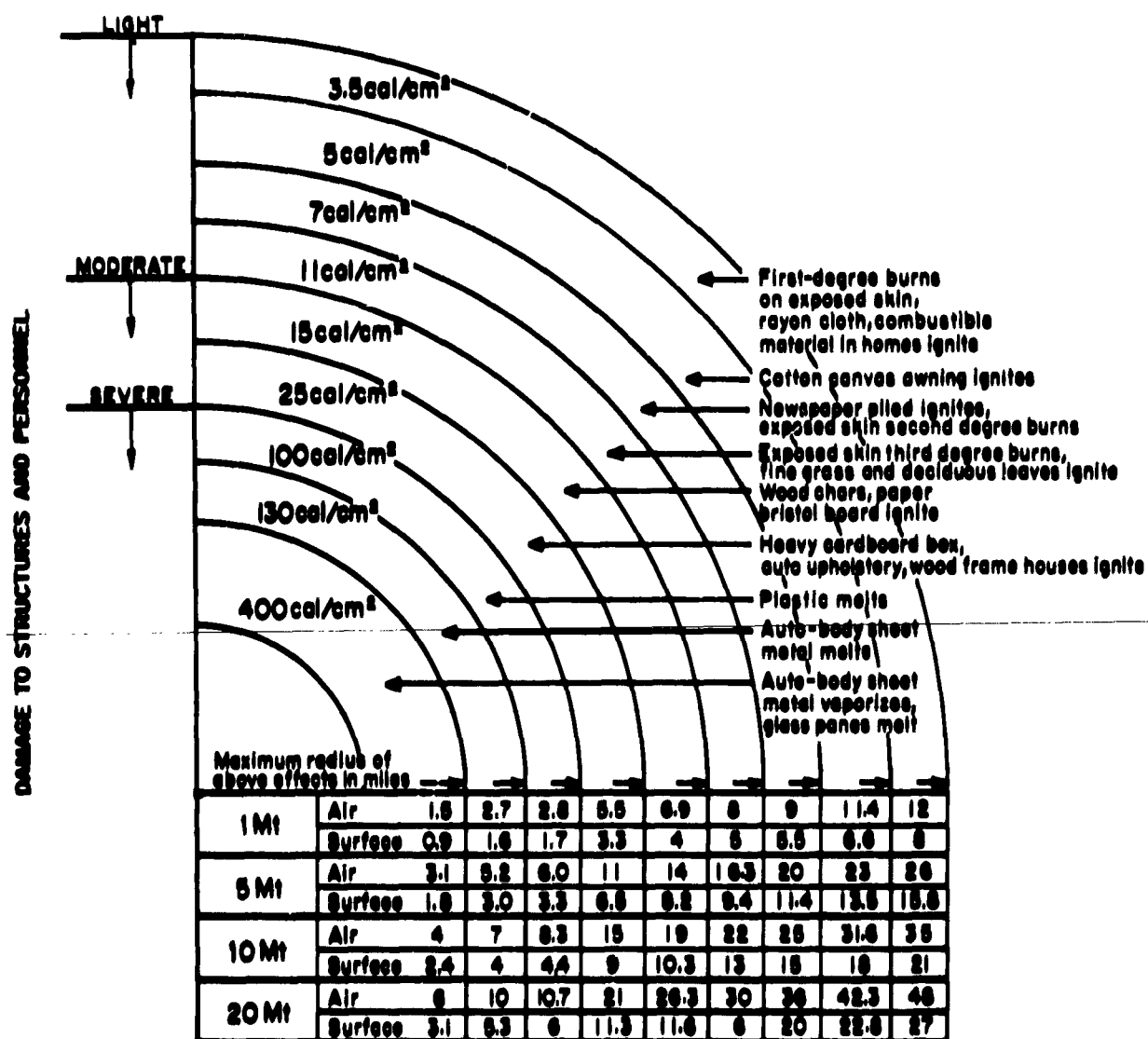


Figure 5.—RANGES FROM GROUND ZERO FOR VARIOUS THERMAL RADIATIONS AND DAMAGE EFFECTS AS FUNCTION OF THE ENERGY YIELDS

Note: $1 \text{ cal/cm}^2 = 3.7 \text{ BTU/ft}^2$

INITIAL NUCLEAR RADIATION

General Properties

With the explosion there is the release of a burst of "initial radiation" (defined as the radiation emitted within the first minute following detonation) - about 5 percent of the bomb's total energy - that is lethal over an area roughly the size of the fireball. High energy neutrons and gamma rays represent the most significant components of this radiation.

Effects on Personnel

The initial radiation effect is generally overshadowed by those effects from blast and shock which may cause almost total destruction within a radius considerably larger than that which is seriously affected by the initial nuclear radiation.

BLAST AND SHOCK

General Properties

The blast or shock wave, which follows directly after the thermal flash, represents about 50 percent of the weapon energy. The blast wave starts as a high pressure shock front, traveling somewhat faster than the speed of sound. After a few seconds, a negative pressure phase follows. The effect is to first squeeze and then expand or explode structures and human tissues. Along with this action there will be short wind gusts of high velocities. Near ground zero, pressures and winds are higher in a surface burst than an air burst. Farther out, an air burst creates stronger pressures and winds because the blast wave bounces off the earth and reinforces the primary wave to form the so-called "Mach front",

Material Damage Effects

Much of the material damage caused by a nuclear explosion is due, directly or indirectly, to the blast wave which accompanies the explosion. The majority of conventional structures will suffer some damage when the overpressure in the blast wave, i.e., the excess over atmospheric pressure, is about one-half pound per square inch or more. Figure 6 indicates expected overpressure and probable damage effects at varying distance zones from the center of a burst (ground zero). In areas of heavy blast damage, fires will be started by broken gas mains and electrical short circuits, and will feed on the kindling produced by the blast.

Another important consequence of the blast wave is the formation of many flying missiles consisting of bricks (and other masonry), glass, pieces of wood and metal, etc. These cause considerable amounts of secondary damage to structures and utilities, and numerous casualties even in lightly damaged areas. In addition, large quantities of debris result in blockage of streets, thus making rescue, fire fighting and utility repair operations extremely difficult.

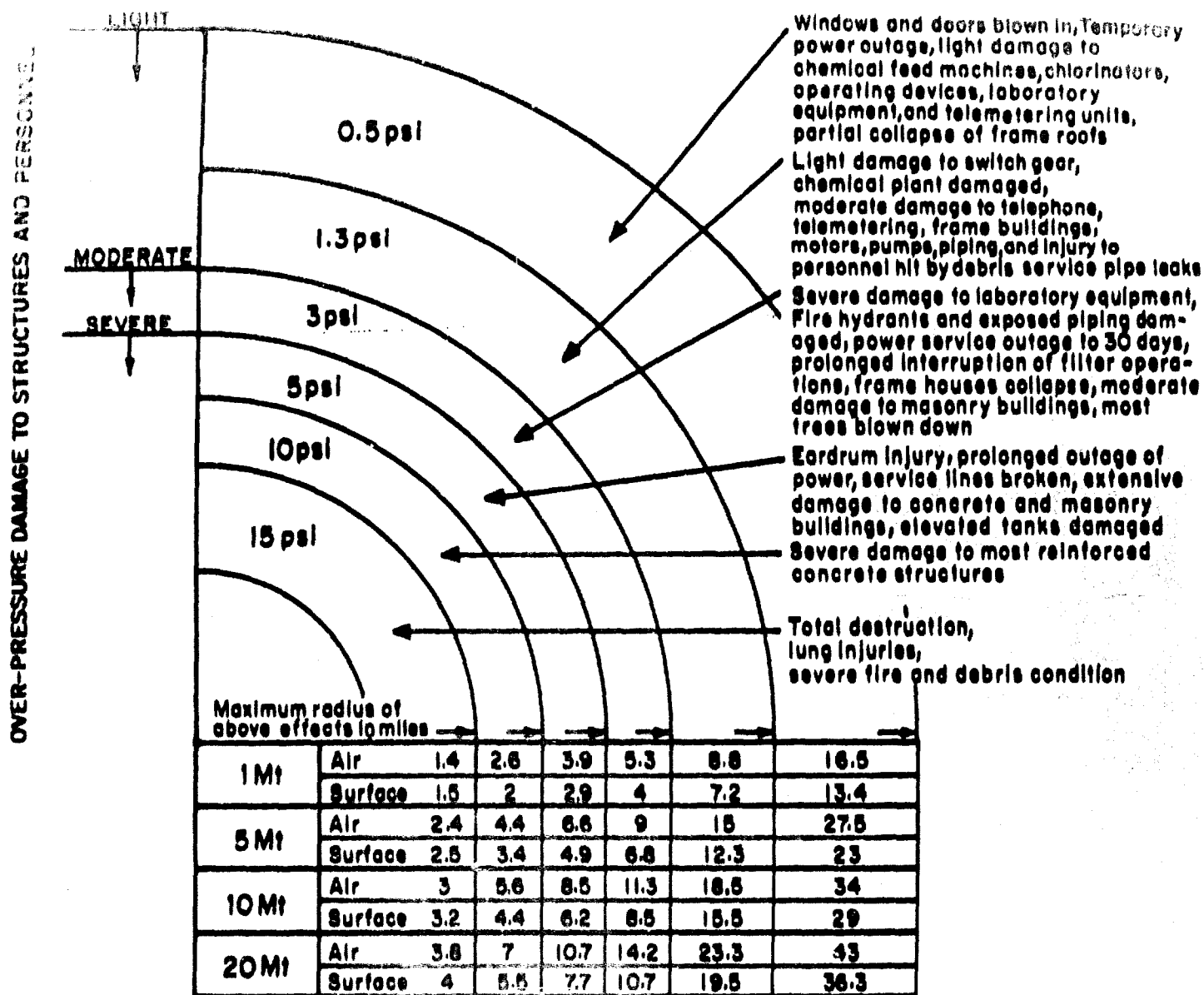


Figure 6.— RANGES FROM GROUND ZERO FOR VARIOUS OVER-PRESSURE AND BLAST DAMAGE EFFECTS AS FUNCTION OF THE ENERGY YIELDS

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Effects on Personnel

For ease of understanding, the effects of blast on personnel are referred to as either direct or indirect. Among the direct effects are those due to overpressure, such as damage to the eardrums and the lungs. These occur at close-in distances (Figure 6).

An indirect type of injury can arise from displacement of the body as a whole by dynamic (or wind) pressure and its resulting impact with a hard surface. This can be experienced at distances where the overpressure is relatively low, because the maximum wind velocities in the open can still be quite high. Because of the relatively slow speed of the blast wave (as compared to thermal radiation), there is often time to take evasive action such as dropping flat or seeking shelter below ground.

Injury to individuals both inside and outside a structure may occur because of the blast damage to that structure. Persons in the interior of the building can be injured and trapped by collapse and fire, and those outside can be hurt by flying debris. These injuries could be quite numerous over the area in which the overpressure is about 2 pounds per square inch or more. For these and other reasons, an important aspect of protection is an understanding of the relative ability of different structures to withstand damage from air blast.

SUMMARY OF INITIAL EFFECTS

Over-all Effects

When a nuclear weapon of known yield is detonated on the surface or at a particular height in the air, the ranges of the immediate effects are fairly well defined. For example, there will be an area surrounding ground zero within which the destruction due to blast and shock, and accompanying fires, will be so great that the survival of inhabitants in conventional structures is improbable. At considerably greater distances the immediate effects will be weaker and damage to structures will be minor, e.g., broken windows and damage to window frames and doors. The radiation from fallout may be significant in this region, but this is a delayed effect which will be considered later. Between the zone of total destruction and the area at which damage is not significant, there is a region in which protective measures can determine whether inhabitants survive, with little or no injury, or whether they become serious casualties.

Initial Effects And Water Supply Systems

An evaluation of the initial effects of a nuclear explosion - thermal radiation, initial nuclear radiation and blast - as related to water utilities and personnel lead to certain pertinent conclusions:

- (1) Nuclear weapons are potent destructive agents.

- (2) It is not feasible, if not impossible, to design and provide total protection for a water supply system.
- (3) Depending upon their distance from ground zero, personnel have little time to take cover.
- (4) Individual survival is the principal objective at time of the weapon detonation and immediately thereafter.

RESIDUAL NUCLEAR RADIATION

General Properties

The delayed effects of a nuclear explosion are associated with the radioactivity present in the fallout. Residual radiation (defined as that which is emitted later than 1 minute from the instant of explosion), while representing only about 10 percent of the total weapon energy, is nevertheless a highly important consideration. Being distributed over an area much larger than that in which blast, heat and initial radiation are significant, it is possible for people to become casualties at such distances from the explosion that the immediate effects are negligible or completely absent.

Figure 7 illustrates the general development and pattern of nuclear radiation early fallout. It is convenient to consider the fallout in two parts, namely, early (local) and delayed (world-wide). Early fallout is defined as that which reaches the ground during the first 24 hours following a nuclear explosion. It is capable of producing radioactive contamination over large areas with an intensity great enough to represent an immediate health hazard. Delayed fallout consists of very fine particles which settle in low concentrations over a considerable portion of the earth's surface. Because of the reduced intensity of radiation as a result of radioactive decay during the relatively long time the fallout remains suspended in the atmosphere, the delayed fallout generally poses no immediate danger to health, although there may be a long term hazard especially through ingestion of contaminated food and water.

Compared to an air burst, a surface burst will contribute much more radioactive debris to the atomic cloud. Thus, heavy local fallout is associated with this type of nuclear explosion while relatively little early fallout is produced by an air burst.

Pattern of Fallout Distribution

The early fallout from a surface burst will begin to reach the ground within several minutes after the explosion at close-in locations, and at increasingly later times at greater distances from ground zero, depending on the effective wind speed and direction. At distances of several hundred miles from the explosion, the fallout may not commence until as late as 24 hours after the burst time. Furthermore, several hours may elapse between the time of arrival of the fallout at any point and the time when deposition is essentially complete.

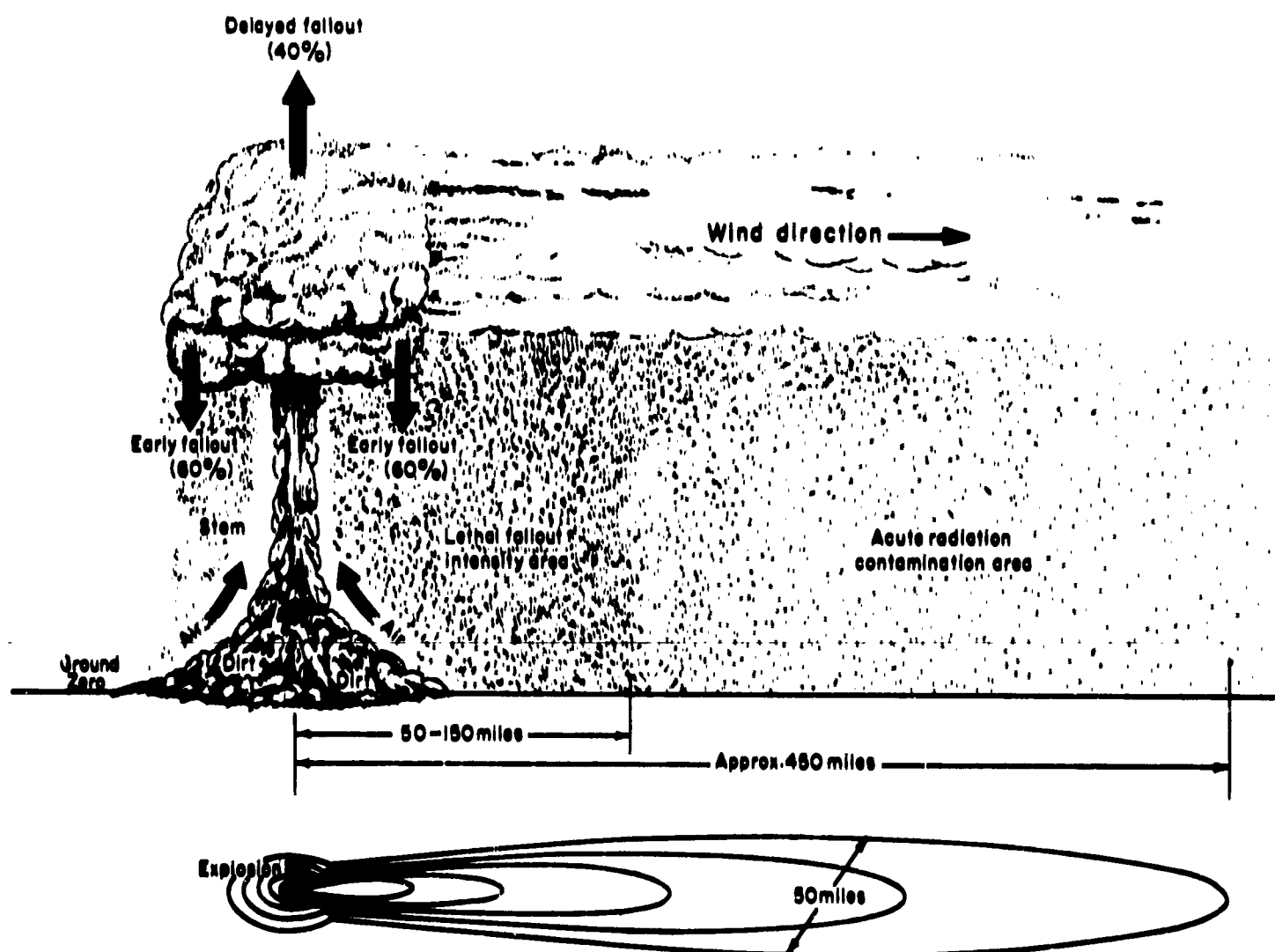


Figure 7.—IDEALIZED EARLY FALLOUT PATTERN FOR SURFACE BURST

Theoretical calculations to determine the distribution of local fallout usually assume that the wind blows in just one direction. Under such conditions, radioactive fallout will tend to settle in a cigar-shaped pattern (Figure 7), with radiation intensity diminishing in the downwind direction and toward the outside edges.

In practice, however, winds at different altitudes move in different directions at different speeds and actual patterns of fallout tend to be highly irregular (Figure 8). Thus the use of area reports on general radiation levels as an estimate of hazards in a local area may not be reliable. The only sure answer is to measure radiation locally.

Rate of Decay

In any group of fallout particles, there will be a wide variety of isotopes, each with a different decay rate. For mixed fission products the radiation level starts high but drops quickly, as short half lived isotopes decay. An easy rule of thumb is that for each increase in time by a factor of seven, the radiation level decreases by a factor of ten. For example, the radiation level at the end of 7 days will have fallen to roughly one-tenth of that at the end of 1 day.

Effects on Personnel

Radiation hazards stem from the fallout particles themselves. The air through which fallout passes, and the surfaces on which it settles, do not themselves become radioactive. Remove the particles and there is no danger.

Alpha and beta radiations from fallout particles penetrate such a short range that they are dangerous only if inhaled, ingested or contacted directly. Gamma radiation is the major hazard. It can be effective a considerable distance from the particle and has great penetrating power. For example, at 3 feet above the ground, roughly 50 percent of the dose rate received in the center of a large, flat, uniformly contaminated area comes from distances greater than 50 feet away, and about 25 percent from distances more than 200 feet away. Thus, complete removal of the contaminated surface from a circle 200 feet in radius would reduce the dose rate in the center to about one-fourth of its original value.

Individual exposure to radiation dose intensities may vary from almost insignificant rates at locations distant from the burst to rates well in excess of 1,000 roentgens per hour at closer in points. As shown earlier, factors such as weapon yield, type of burst and wind directions and velocities determine this fallout pattern.

The product of the average dose rate and time of exposure determine the total amount of radiation dose experienced by an individual. Table I shows the effects of various amounts of short term radiation exposure (total received within a few day period) on humans. The effects also depend on such factors as age and general health.

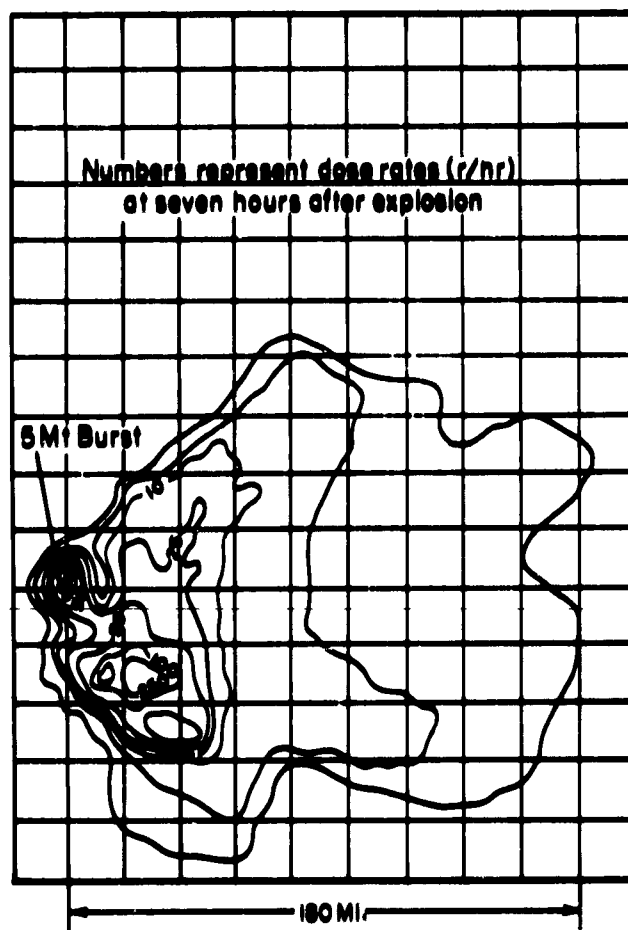


Figure 8.—ACTUAL FALLOUT CONTOUR (5Mt)

TABLE I
BIOLOGICAL EFFECTS OF EXPOSURE ON PERSONNEL

| <u>Short-term Dose</u> | <u>Visible Effect</u> | <u>Able to Work</u> |
|------------------------|--|---------------------|
| 50 r | No visible effects. | Yes |
| 75-100 r | Brief periods of nausea on day of exposure in about 10% of the group. | Yes |
| 200 r | As many as 50% of this group may experience some of the symptoms of radiation sickness. Although only 5% to 10% may require medical attention, no deaths are expected. | Yes |
| 450 r | Serious radiation sickness in most members of the group followed by death to about 50% within two to four weeks. | No |
| 600 r | Serious radiation sickness to all members of the group followed by death to almost all members within one to three weeks. | No |

Studies suggest that it is possible to survive even greater total doses accumulated in small units over a longer period of time.

Protection from Fallout

The seriousness of the hazards from radioactive fallout to personnel is apparent and emphasizes the importance of protection for the entire population. It is during the period immediately following the nuclear explosion, when the radiation level is at its highest, that this protection is most important.

Information has been published that describes procedures and standards for evaluating the potential of existing structures as fallout shelters and for modifying such structures to improve their effectiveness in this respect. This subject as related to waterworks facilities and personnel will be discussed in later chapters of this manual.

Residual Effects and Water Supply Systems

The immediate objective for personnel surviving the initial effects of a nuclear explosion is to avoid becoming a casualty from the residual effects which, while more subtle in nature, nevertheless can prove fatal. At the same time, quick recovery of operation of the water supply system is another important objective because available water is vital for:

- (1) human survival
- (2) controlling fire damage
- (3) decontamination operations

To most efficiently accomplish these objectives, a disaster plan is needed that provides the means to evaluate when and how to initiate rapid postattack recovery procedures.

LIKELY TARGETS, ATTACK SIZES AND PATTERNS

The kind and size of possible enemy attack patterns are subject to considerable public speculation. Some recognized national authorities have made systematic analyses of attacks to be expected as a result of various enemy objectives, and these may be summarized as follows:

- (1) A limited attack aimed at the destruction of U. S. offensive power.
- (2) A heavier attack intended to neutralize total U. S. military potential.
- (3) A very heavy attack intended to reduce the U. S. to impotency.

This manual cannot undertake a complete analyses of the various attack systems, conditions and operating factors involved; however, some reasonable generalizations can be made:

- (1) Any attack system regardless of objectives, must be aimed at the destruction of U. S. offensive military power. This means attacks on Strategic Air Command bases with nuclear weapons, and probably with more than one bomb per target.
- (2) Attempts to neutralize total U. S. military potential probably means attacks on all military bases with nuclear weapon yields commensurate with the size and importance of the individual base.
- (3) Attempts to reduce the nation to impotency might well take the form of additional attacks on cities (populations of 50,000 plus). Surface bursts of "dirty" weapons to increase the fallout problem away from the targets may also be used.
- (4) It is reasonable to assume that there would be some aiming errors - perhaps by as much as ten miles.

Significance to Water Supply Systems

From the above conjectures, it may be further assumed that an evaluation of potential damage and hazards to any given water supply system and its personnel would depend upon their geographical relationship to likely targets, weather patterns and resulting nuclear weapon effects.

REFERENCES

- (1) The Effects of Nuclear Weapons, Revised Edition April, 1962, USAEC
- (2) Nuclear Attack and Industrial Survival, McGraw-Hill Publishing Co.
- (3) Personal and Family Survival, (SM-3-11) D.O.D. OCD
- (4) Community Shelter Report - City of Livermore, California,
California Disaster Office

CHAPTER III

VULNERABILITY ASSESSMENT

INTRODUCTION

The vulnerability of a water system to a nuclear attack is a measure of the degree to which the service of an adequate supply of water by the utility would be adversely affected by the initial and postattack effects of the nuclear explosion or explosions. One of the most important parts of a water utility's advance preparation program is the assessment of the utility's vulnerability to such an attack. The purpose of the vulnerability assessment is to provide through vulnerability reduction measures for the continuity of postattack operations. The results of the vulnerability assessment can be used to consider priority levels in the over-all postattack condition as well as to determine the extent of "hardening" necessary to accomplish various degrees of protection. As a result of the vulnerability studies definite attainment goals should be formulated and time-phased for reasonable achievement dates.

The vulnerability of a water system extends beyond structural considerations. It also encompasses raw materials; equipment required for operation; and personnel protection, availability and training. Vulnerability studies will also point out the various operations which may be affected and should be a basis for the provisions of possible methods of repair and improvisation which may be used to restore a particular operation. The vulnerability assessment should include the following:

- 1) Source facilities
- 2) Treatment facilities and processes
- 3) Transmission facilities
- 4) Storage
- 5) Distribution facilities
- 6) Structures
- 7) Power
- 8) Communications
- 9) Equipment
- 10) Material and supplies
- 11) Manpower
- 12) Emergency procedures

The effects of nuclear weapons--blast, thermal and fallout--are discussed in Chapter II. These effects must be considered in determining vulnerability. They would vary according to the size and yield of the individual weapon, type of burst (air, surface or subsurface), altitude of the air burst, distance from the burst, geography, meteorological conditions, time of day

and the nature of the materials that would be affected. All of these variables cannot be considered simultaneously; however, it is possible to review the effects of each variable independently and then consider a reasonably probable over-all effect from the major or significant variables.

The results of a specified blast can be estimated using data from studies that have been made of nuclear weapon phenomena. The range of effects in which we are interested is from the point of first noticeable damage up to complete and irreparable destruction.

The effects of a nuclear explosion on a structure are primarily due to blast and shock forces and to a lesser extent, thermal radiation. On personnel and water supply, initial radiation and radioactive fallout are also of importance. Blast waves act to deform and fragment structures, thermal radiation acts to ignite combustibles and melt non-combustibles, while radioactivity acts to contaminate the area and thereby adds to the difficulties in accomplishing repair and rebuilding.

This chapter has been prepared so as to guide water utility managers in assessing the vulnerability of their own system to nuclear attack and the resulting post nuclear effects. Criteria are given and an orderly procedure is outlined for making such an assessment. Finally a detailed example is presented giving an ideal assessment of a small to medium size utility.

CRITERIA OF VULNERABILITY TO BLAST, THERMAL AND IONIZING RADIATION EFFECTS

Blast wave, thermal radiation and ionizing radiation have been reviewed in the preceding chapter. Using the information developed consideration will now be given to the response of various targets to these effects. Criteria of damage will be reviewed.

General Criteria

The damage resulting from blast or shock waves can be related to overpressure (psi), that from thermal radiation to energy (cal/cm²) and that from ionizing radiation to radiation dose (roentgen or roentgen/hr).

The effects of blast wave overpressure on structures vary considerably depending upon the material of construction as well as the over-all strength of the structure. This is demonstrated in Figure 6 of Chapter II. Most structures suffer some damage (damage in some portions) when the overpressure exceeds about one-half psi, frame houses may collapse at two psi, most conventional houses will be damaged beyond repair at five psi, while the structural members of blast resistant structures, such as steel reinforced concrete buildings, may withstand over 10 psi. Motor vehicles may withstand about 5 psi.

Thermal radiation will ignite materials and cause skin burns and eye injuries. Some combustible materials customarily found in homes can be ignited at less than 3 to 6 cal/cm² shown in Figure 5. Eye injuries can

occur at considerably greater distances from the explosion than those at which first-degree burns will be received.

The effects of ionizing radiation will also vary as shown in Table I. Early fallout is capable of producing radioactive contamination over large areas with an intensity great enough to represent an immediate biological hazard. Delayed fallout generally poses no immediate danger to health although there may be a long term hazard.

Affected Areas

The areas affected by blast and shock, initial radiation, thermal radiation and residual radiation can be separated into three general classes. These classes will depend upon the intensity of each of the destructive phenomena and on the way in which they interact with the environment. The three classes, located at varying distances from the center of the nuclear burst, can be related to the following zones:

- Zone 1 - The area closest to the site of the burst where the blast, thermal and ionizing radiation effects will all be evident. Structural damage will be the primary gross effect noted here along with fire damage and a need for shielding personnel from radiation for some period of time.
- Zone 2 - Large areas primarily downwind from the target where fallout from residual radiation will be the main concern. In addition fires may also reach this zone. The primary concern in this zone will be the shielding of personnel.
- Zone 3 - Areas at a sufficient distance from the blast such that no direct effects from the nuclear explosion are noted. However, such areas may be surrounded by others experiencing the effects noted for Zones 1 and 2 and, therefore, the inhabitants may be unable to leave this zone for a limited period.

Zone 1, and to some extent Zone 2, can be further broken down into areas of severe, moderate, and light damage. The limits of these areas will vary as shown in Figures 5 and 6 of Chapter II according to whether blast, thermal radiation or radioactivity is being considered. The various degrees of damage resulting from a nuclear burst will now be considered.

Blast Effects

In the air burst, 50% of the energy is in the blast on pressure waves, 35% in thermal radiation and the remaining 15% in radioactivity.

The shock front of the blast wave spreads from the fireball like a ripple a little faster than the speed of sound. The blast from a one-megaton weapon would almost completely destroy all buildings within two miles and severely damage everything but massive buildings up to three miles. The

range of destruction is proportional to the cube root of the bomb's energy; thus the damage by blast from a 20-megaton bomb would extend ten times farther than that of the 20 KT Hiroshima size weapon.

Thermal Radiation Effects

In the severe thermal radiation damage zone, fire may spread among the debris produced by the blast. A fire storm consists of a wind blowing toward the burning area from all directions. Because of the strong inward draft at ground level the fire storm can limit the spread of the fire beyond the initial ignited area; however, virtually everything combustible within the region will be destroyed.

In the moderate thermal radiation damage zone many combustibles will ignite and there will be a good number of scattered fires which may join and become a "conflagration" or "sweep conflagration". A one-megaton bomb produces a flash hot enough to convert more than half a million tons of water into steam. It can cause third degree burns to people 13 miles away while the 20 MT would extend this to 45 miles; while eye injuries would occur at even much greater distances.

In the light thermal radiation zone, some scattered fires will be noted. Any person in the open will receive second or third degree flash burns.

Ionising Radiation Effects

The effect of radioactivity on individuals from a nuclear explosion will depend on the dose received as well as the individual tolerance. Protection by sheltering is all important. For those in the open at the time of a blast initial nuclear radiation at a radius of 1.5 and 2 miles for a 1 and 10 megaton weapon respectively can result in a 100% death rate. A nuclear radiation shield would have to be very massive to afford effective protection from initial radiation at distances close to the burst.

Residual radioactivity, early and delayed, will extend far beyond the area of blast, thermal and initial radioactivity effects. Because of this, it is possible for people to become casualties at such distances from the explosion that the immediate effects are negligible or completely absent. It is difficult to designate the area that would be affected by residual radiation in a reasonably accurate manner because it is dependent upon so many conditions including energy yield of the explosion, relative contributions of fission and fusion to the total yield, the height of burst, the nature of the surface over (or on) which the detonation occurs, rainfall and especially windspeeds and directions over a considerable height. It is certain, however, that a surface burst in the megaton range will lead to contamination of very large areas by early fallout which will reach the ground within several hours after the explosion.

COMPUTATION OF PROBABLE EFFECTS

Blast Effects

The damage resulting from aerodynamic shock waves can be related to overpressures. Theoretically, the pressure which occurs at a given distance from an explosion is proportional to the cubic root of energy yield. According to this law, if D_1 is the distance (or slant range) from a reference explosion of W_1 megaton at which a certain overpressure or dynamic pressure is attained, then for any explosion of W megaton energy this same pressure will occur at distance D as given by

$$D = \left(\frac{W}{W_1} \right)^{1/3} D_1$$

This law also may be applied to distances from ground zero as well as to distance from the explosion for air bursts having different energy yields.

The relationships between weapon yields, possible damage and extended distances with respect to overpressure for surface bursts are summarized in Figure 6, Chapter II.

Thermal Radiation Effects

Thermal radiation resulting from a nuclear explosion travels with the speed of light and will transport energy varying approximately linearly with the yield and atmospheric transmittance and inversely as the square of the distance as given by

$$Q \text{ (cal/sq cm)} = \frac{1000 \text{ fWT}}{D^2}$$

for a surface burst.

Where D is distance in miles from explosion

W is weapon yield in megatons

T is atmospheric transmittance

f is fraction factor

$f = 1.04$ for air burst

$f = 0.8$ to 0.5 for surface burst.

For example, if the thermal radiation is 11 cal/cm^2 for a surface burst of a 1-MT weapon at a slant range of 5 miles, then with unchanged atmospheric conditions, the same radiation exposure will be extended to 13 miles for a 10-MT weapon.

The effect of visibility on transmittance of thermal energy is shown in Figure 9.

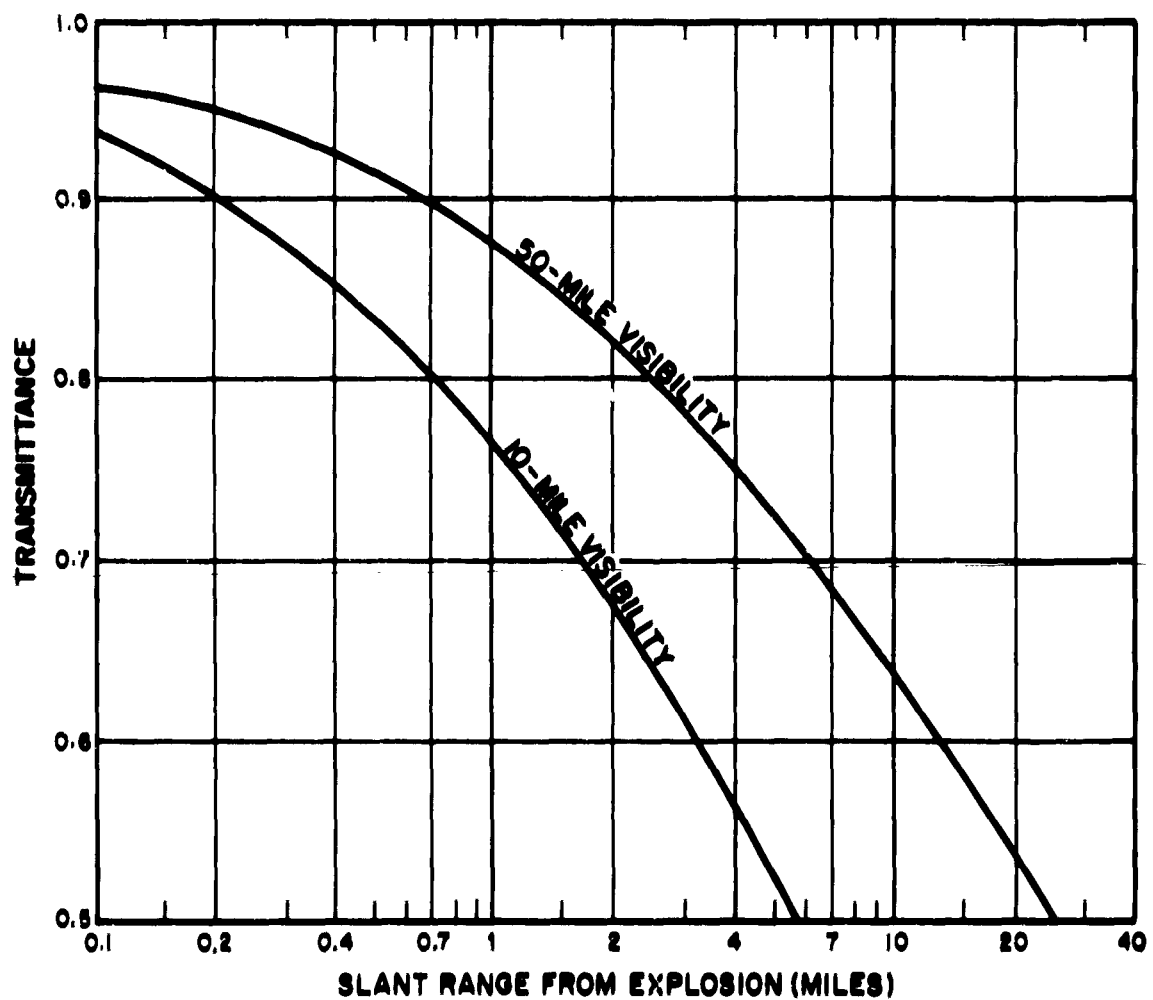


Figure 9.—ATMOSPHERIC TRANSMITTANCE AS A FUNCTION OF DISTANCE FOR VISIBILITIES OF 10 MILES AND 50 MILES

The thermal radiation produced by an air burst can be determined from the explosion yield and slant range using Figure 10. This figure has been prepared for a reasonably clear state of the atmosphere, that is, a visibility of 10 miles or more. Under hazy atmospheric conditions, or in the event of a surface burst, the distance obtained from Figure 10 may be decreased. Similarly, a layer of dense cloud or smoke between the target and the point of burst will decrease the distance over which fires may be started.

The spread of fires in a city depends upon many conditions including weather, terrain and closeness and combustibility of the buildings. If other circumstances are more or less the same, the most important criterion of the probability of fire spread is the distance between buildings. Figure 11 provides a rough estimate of the probability of fire spread accompanying a nuclear explosion when a large number of small fires are started directly by thermal radiation and indirectly in other ways.

The possibility of burns of any particular degree of severity occurring can be related to radiant exposure, explosion yield and distance from the center of explosion.

Ionizing Radiation Effects

The biological effect of exposure to radiation is given in Table I. Radiation dose could be calculated by multiplying the average dose rate by length of exposure (e.g. 3 roentgens per hour times 4 hours equals 12 roentgens). As discussed in Chapter II, the radioactivity dose rate decreases by a factor of 10 for every sevenfold increase in time after explosion. Calculations of dose rates in early fallout can be made from Figure 12. Total accumulated dose can be obtained from Figure 13. To determine the total radiation dose which might be received while doing outside repair work after a nuclear attack Figures 12 and 13 can be used.

To illustrate dose rate calculations, suppose that an individual became exposed to a certain quantity of gamma radiation from early fallout 2 hours after a nuclear explosion and the dose rate, measured at that time, were found to be 1.5 roentgens per hour. What will be the total dose received during the subsequent 12 hours, i.e. by 14 hours after explosion?

The first step is to determine the unit-time reference dose rate from Figure 12. It is seen that:

$$\frac{\text{Dose rate at 2 hours after explosion}}{\text{Unit-time reference dose rate}} = 0.40$$

and since the dose rate at 2 hours is known to be 1.5 roentgens per hour, the reference value is $1.5/0.40 = 3.8$ roentgens per hour. Next, from Figure 13,

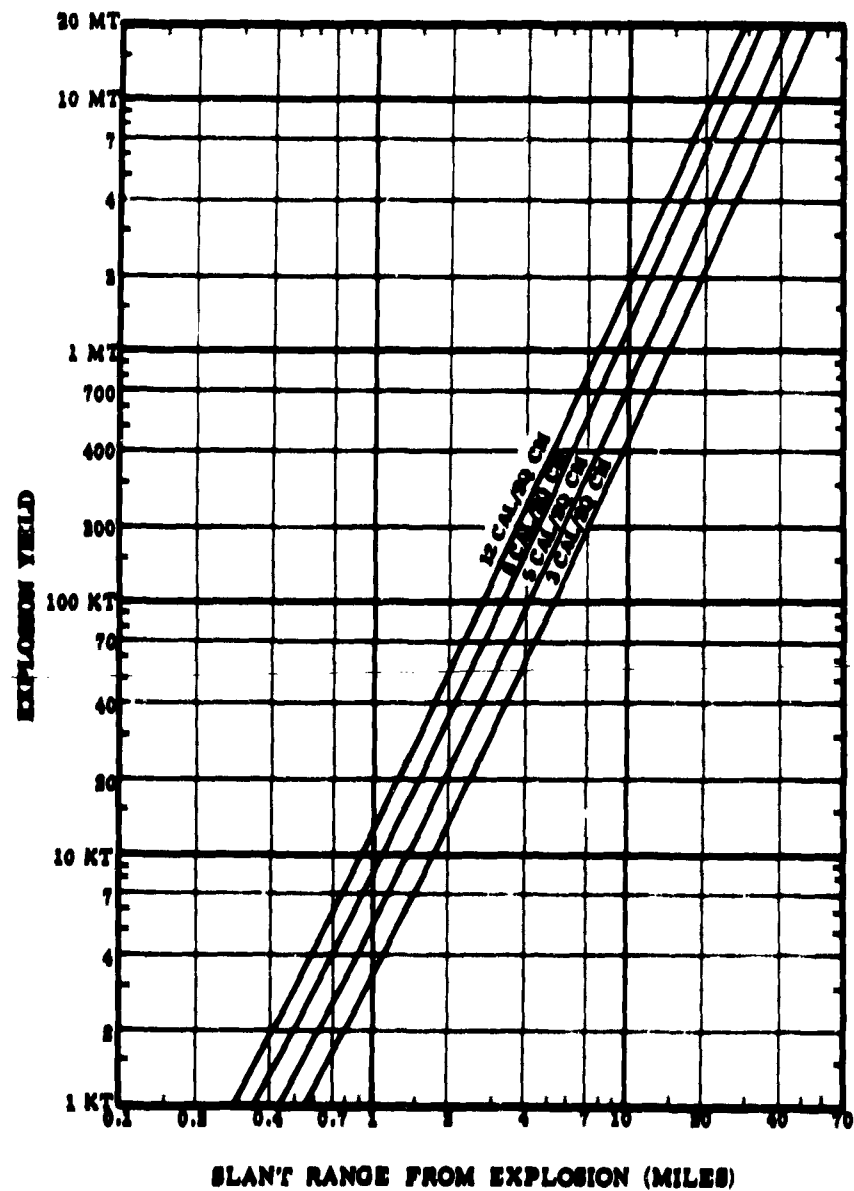


Figure 10.—SLANT RANGES FOR SPECIFIED RADIANT EXPOSURES AS FUNCTION OF ENERGY YIELD OF THE EXPLOSION

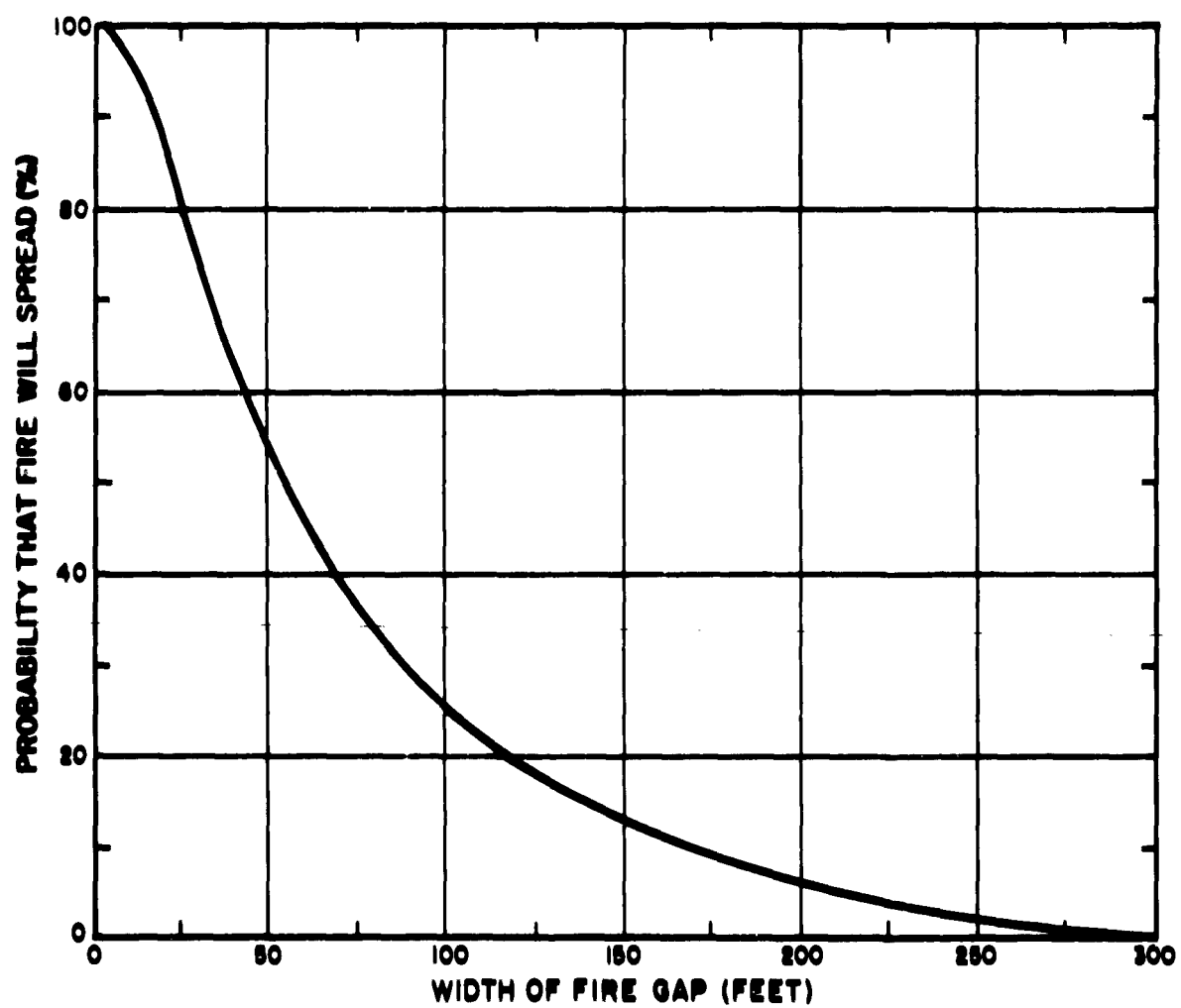


Figure 11. — WIDTH OF GAP AND PROBABILITY OF FIRE SPREAD

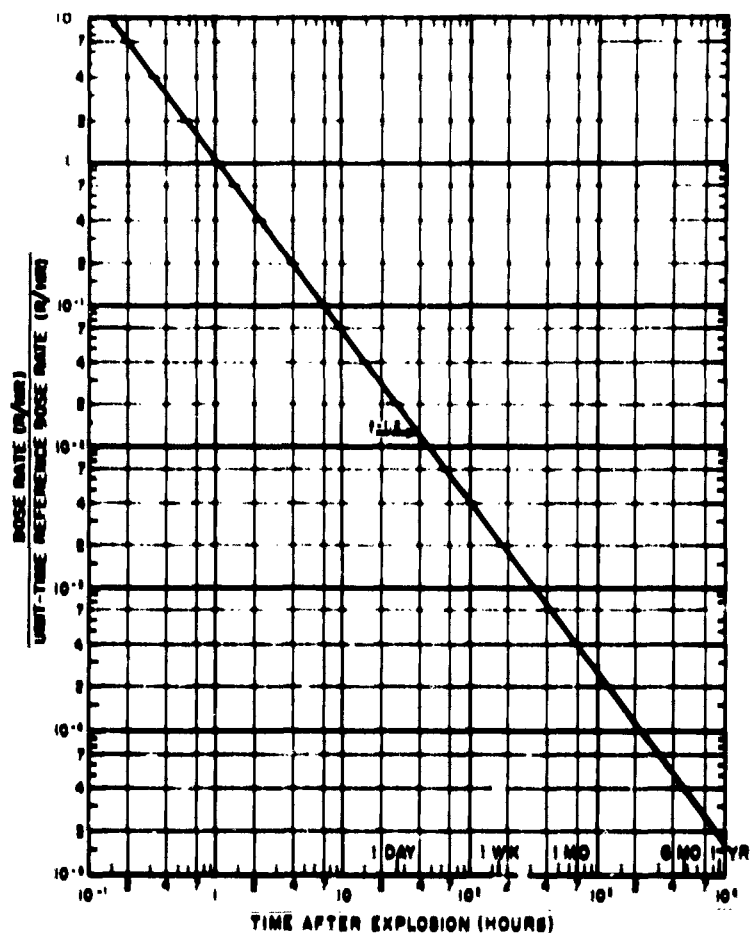


Figure 12.- DECAY CURVE FOR EARLY FALLOUT

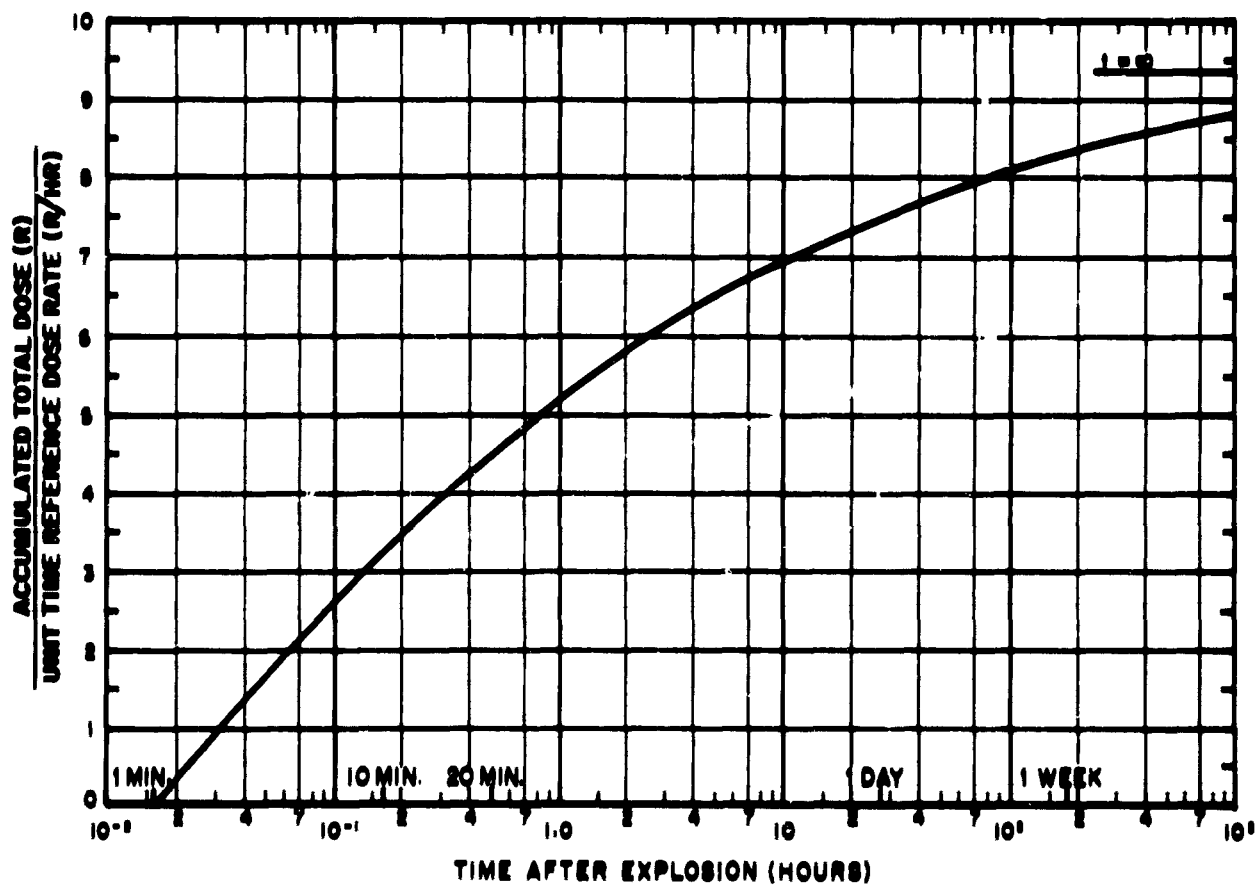


Figure 13.- CURVE FOR DETERMINING ACCUMULATED DOSE

it is found that for 2 hours and 14 hours respectively, after the explosion

$$\frac{\text{Total dose at 2 hours after explosion}}{\text{Unit-time reference dose rate}} = 5.8$$

and

$$\frac{\text{Total dose at 14 hours after explosion}}{\text{Unit-time reference dose rate}} = 7.1$$

Hence, by subtraction:

$$\frac{\text{Dose received between 2 and 14 hours after explosion}}{\text{Unit-time reference dose rate}} = 1.3$$

The unit-time reference dose rate is 3.8 roentgens per hour, and so the total dose received in the 12 hours, between 2 and 14 hours after explosion, is $3.8 \times 1.3 = 4.9$ roentgens.

With the aid of Figures 12 and 13, many different types of calculations relating to radiation dose rates and total doses received from early fallout can be made.

"Dose Rate" and "Entry Time - Stay Time - Total Dose" nomograms shown in Figures 14 and 15 respectively are especially useful for finding the dose rate and earliest entry time into an area to perform a job requiring a known stay time. Illustrated examples are shown in the following pages.

Illustrated Examples of Dose Rate, Stay Time and Total Dose Calculation

Example 1 (Dose Rate Nomogram)

Given = The dose rate at H + 12 is 50 r/hr

Find = The dose rate at H + 18

Solution = Using a straight edge, connect 50 r/hr on the "Dose Rate at H + t" column with 12 hours on the "Time after Burst" column and read 970 r/hr on the "Dose Rate at H + 1" column. Pivot the straight edge to connect 970 r/hr on the "Dose Rate at H + 1" column with 18 hours on the "Time After Burst" column read the answer from the "Dose Rate at H + t" column.

Answer = 31 r/hr

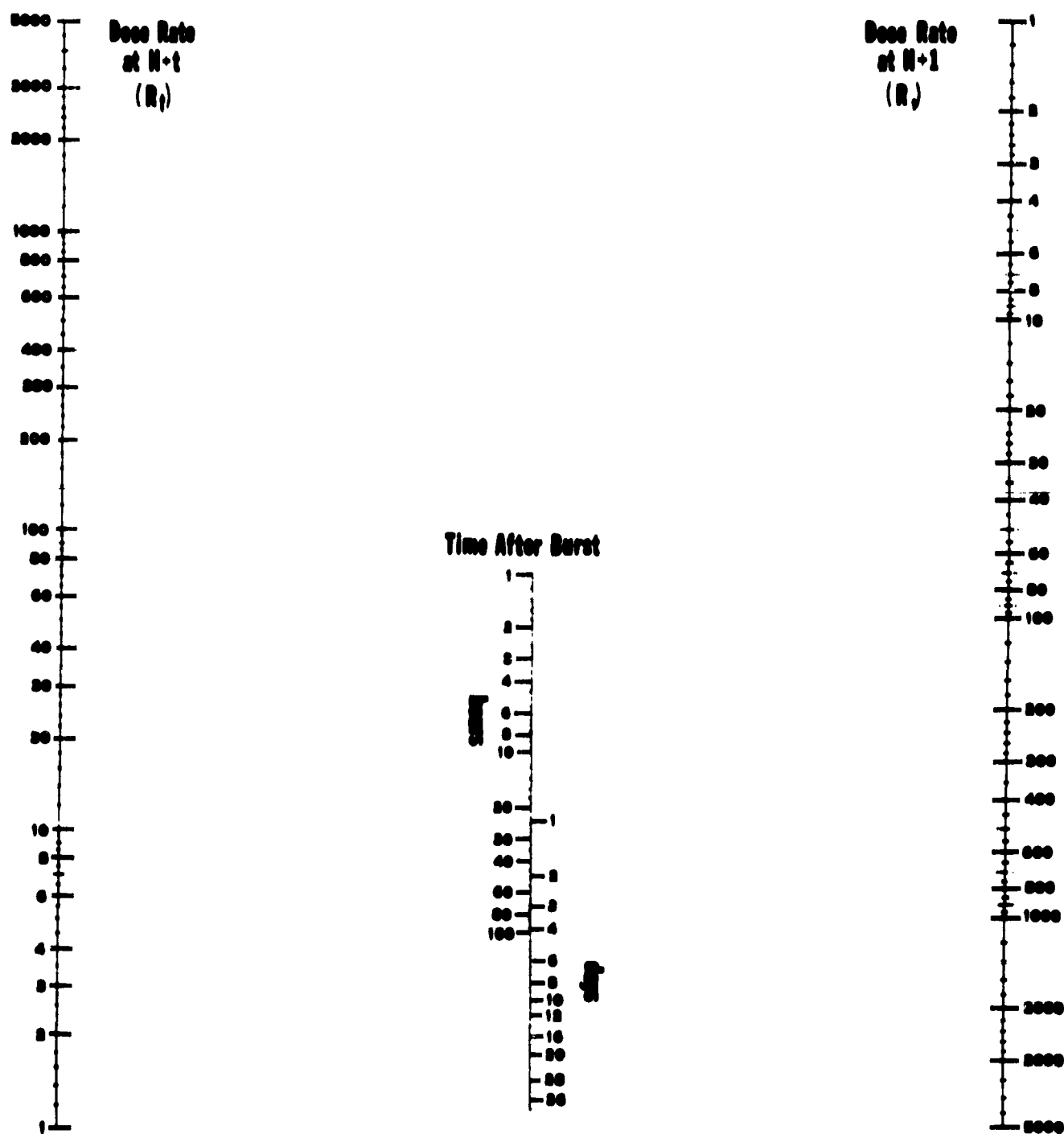


Figure 14. —DOSE RATE NOMOGRAM
(R/hr)

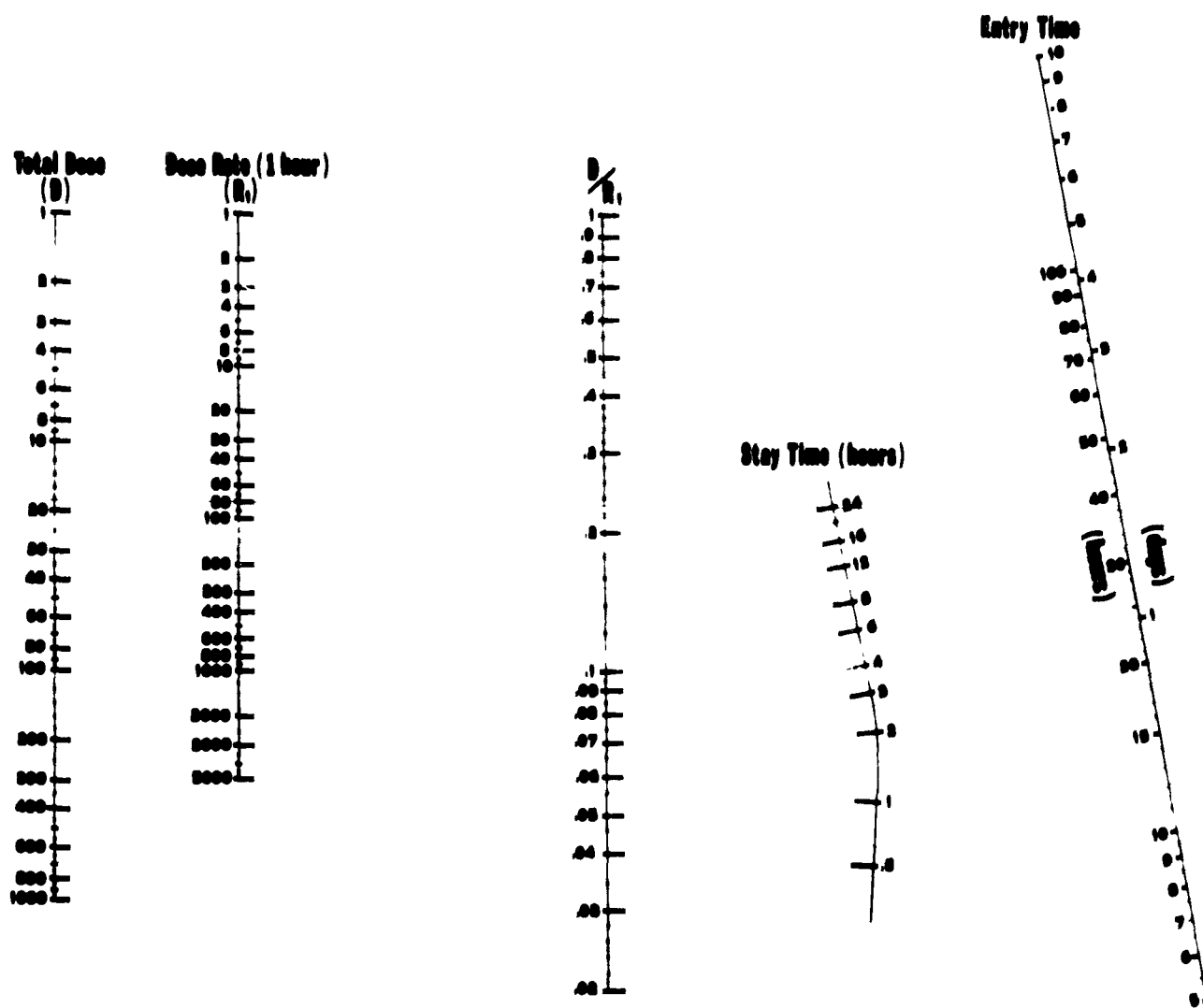


Figure 15. — ENTRY TIME-STAY TIME-TOTAL DOSE NOMOGRAM
(R/hr)

Example 2 (Entry-Time - Stay-Time - Total Dose Nomogram)

Given - Dose Rate at $H + 10$ is 12 r/hr. Entry time is 14 hours and the mission dose is established at 50 r.

Find - Stay Time

Solution - Find the dose rate at $H + 1$ (190 r/hr) as described in Example 1. Using a straight edge, connect 50 r on the "Total Dose" column with 190 r/hr on the "Dose Rate at $H + 1$ " column. This shows 0.26 on the " D/R_1 " column. Connect 0.26 on the " D/R_1 " column with 14 hours on the "Entry Time" column. Read 8 hours on the "Stay Time" column.

Answer - 8 hours

Example 3 (Entry Time - Stay-Time - Total Dose Nomogram)

Given - The Dose Rate at $H + 8$ is 10 r/hr.

Find - The total dose received if a person enters the area at $H + 10$ and remains for 4 hours.

Solution - Find the dose rate at $H + 1$ (120 r/hr) as described in Example 1. Using a straight edge, connect 4 hours on the "Stay Time" column with 10 hours on the "Entry Time" column. This shows 0.21 on the " D/R_1 " column. Connect 0.21 on the " D/R_1 " column with 120 r/hr on the "Dose Rate at $H + 1$ " column. Read the answer from the "Total Dose" column.

Answer - 25 r.

Personnel Shelter

The vulnerability assessment should be especially thorough in reviewing the adequacy of personnel shelters with regard to their construction, location, size and numbers. Although the protection of facilities and personnel from blast effect is essential, the need for the protection of personnel from ionizing radiation is relatively greater as ionizing radiation will affect a much larger area. The protective measures available against hazardous radiation effects of radioactive fallout will be discussed in detail in Chapter IV. Calculations can be made of the protection provided by various types of shelters. The protection factor is the ratio of the radiation dose one would experience outside a shelter to the dose one would receive inside. Table II has been prepared to show the minimum protection factor to prevent 4 days exposure dose from exceeding 200 roentgens under various radiation intensities. Additional information is given in Figure 16 which shows the dose transmission factor for initial gamma radiations of various materials as functions of thickness.

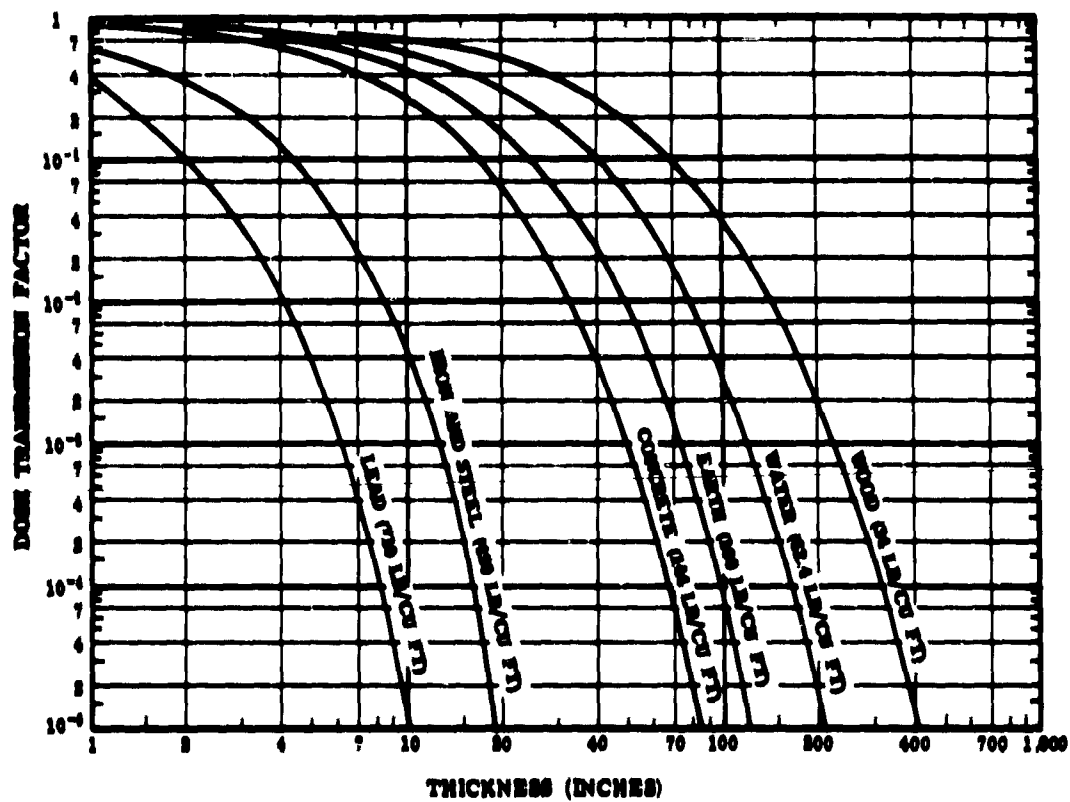


Figure 16.—DOSE TRANSMISSION FACTORS FOR ABOUT 1 Mev GAMMA RADIATIONS OF VARIOUS MATERIALS AS FUNCTION OF THICKNESS

TABLE II

**RADIATION EXPOSURE DOSE - UNSHELTERED PERSONNEL
AND SHELTER PROTECTION FACTOR FOR SURVIVAL**

| Radiation Intensity at (H+1) (r/hr) | Approximate 4 day exposure dose (roentgens) unsheltered personnel | Minimum Protection factor for Survival in Shelter** | Area of U.S.* Involved % |
|-------------------------------------|---|---|--------------------------|
| 50 | 140 | 1 | 50 |
| 50 - 100 | 140 - 290 | 1 - 2 | 13 |
| 100 - 300 | 290 - 870 | 2 - 5 | 17 |
| 300 - 500 | 870 - 1450 | 5 - 8 | 5 |
| 500 - 1000 | 1450 - 2900 | 8 - 15 | 5 |
| 1000 - 3000 | 2900 - 8700 | 15 - 44 | 8 |
| 3000 | 8700 | | <u>2</u> 100% |

* Based on "The Probable Fallout Threat Over the continental United States", by Tec-Ops in which a 4080 MT (2720 fission megatons) attack on both military and industrial targets was assumed.

** Required to reduce the 4-day dose to 200 roentgens or less.

VULNERABILITY OF WATER UTILITY FACILITY AND WATER SUPPLY

A guide for vulnerability assessment of water utility facilities and water supply to blast and shock, thermal radiation and ionizing radiation is shown in Table III.

TABLE III
GUIDE FOR VULNERABILITY ASSESSMENT OF WATER UTILITY FACILITIES

| CHARACTER OF RESPONSE | | | | |
|--|---------------------|--|--|--|
| Facilities | Damage | Blast and Shock | Thermal Rad. | Ionizing Rad. |
| SOURCES | | | | |
| a) Direct stream diversion and impoundment | Light | Increase of turbidity | | |
| | Moderate | Degradation of water quality due to sewage or industrial waste spills. | Fires in watershed area. | Contamination of surface water by fallout. |
| | Severe | Change of stream course, failure of impoundment, damage to intake structures and outage of power. | | |
| | Light (1-2 psi) | Damage to exposed pumping facilities. Short period outage of power. Local repair possible. | Fire damage to pumping unit. | No appreciable effect on supply. |
| | Moderate (2-4 psi) | Contamination by sewage and wastes resulting from piping and structure damage. | | |
| b) Ground water | Severe (4-psi up) | Serious damage to exposed pumping facilities. Submersible units withstand safely. Prolonged power outage. | | |
| | Light (0.5 psi) | Window and door blown in. Damage to exposed operating device, and outage of electric power. | Fire damage to structures. | Contamination of water. |
| | Moderate (3 psi) | Exterior walls crack and filter basin leak. Electric power supply damaged extensively. Pipe gallery may withstand. | | |
| | Severe (5 psi) | Damage to exposed elevated wash-water tank. Pipe gallery withstand. | | |
| | Light (0.5-1.0 psi) | Window and door blown in. Damage to containers, feeders, and operating device. Electric power supply outage. | Fire damage to chemical storage and other facilities | Contamination of water and chemicals |
| c) Laboratory | Moderate (3 psi) | Out of operation due to power supply outage. | | |
| | Severe (5 psi) | Exterior wall badly cracked. | | |
| | Light (0.5 psi) | Short outage of electric power service and telemetering. | Fire damage to equipment, building and chemicals | Contamination of laboratory facilities. |
| | Moderate (3 psi) | Most of laboratory instruments damaged. Electric power service, gas and water supply outage. | | |
| | Severe (5 psi) | Most of laboratory equipments out of use. Prolonged outage of power, gas and water service. | | |

TABLE III

GUIDE FOR VULNERABILITY ASSESSMENT OF WATER UTILITY FACILITIES

| CHARACTER OF RESPONSE | | | |
|---|----------------------|---|---|
| Facilities | Damage | Blast and Shock | Thermal Rad. Ionizing Rad. |
| WATER | | | |
| STORAGE | | | |
| a) Covered Tank | Light (0.5 psi) | Vent openings blown in. Damage to exposed appurtenances. Power service and control facilities outage. Bending of frame roofs. Reservoir remains operable. | Fire damage to exposed appurtenances. Contamination of exposed water. |
| | Moderate (3 psi) | R.C. roof slab crack. Frame roof collapsed. Damage valves and piping. Reservoir remains in service. | |
| | Severe (5 psi up) | R.C. roof collapses. Roof top appurtenances destroyed. Leaks caused by cracking of embankments and side walls. Damage to valves and pipes. | |
| b) Uncovered tank | | Except roof and roof appurtenances, the rest will be almost the same to covered tank. | |
| STRUCTURE | | | |
| a) building | Light (0.5 psi) | Windows and doors blown in, interior partitions of wood frame or brick building crack. | 1) Charring or burning of structures preclude workmen to work areas. |
| | Moderate (3 psi) | Wall framing cracked, roof badly damaged, interior partitions blown down. | 2) Toxic gases created by mass fire. |
| | Severe (5 psi) | Wood frame collapse. R.C. wall shattered. | |
| b) Pumping Station | Light (+) (1-2 psi) | Windows and doors blown in. Damage to exposed appurtenances. Power outage for short period. | |
| *Earthquake resistant | Moderate + (2-8 psi) | Walls cracked and frame distorted. Damage to pumping facility and its appurtenances. Extended outage in power service and telemetering systems. | |
| +Non-earthquake resistant | Severe + (8 psi up) | Walls badly cracked and frame collapse. | |
| c) Distribution main and appurtenances. | Light (2-5 psi) | Damage to exposed mains and fire hydrant. Problems in locating manholes, etc. Damage to control and operation facilities. Loss of water pressure in system. | Fire damage to buildings, pumping facilities and stockpiles. Contamination of exposed water |
| | Moderate (5-10 psi) | Numerous leaks and breaks. Severe damage to fire hydrants and valves. Severe pressure reduction. | |
| | Severe (10 psi up) | Major debris problem in built-up area. | |

TABLE III
GUIDE FOR VULNERABILITY ASSESSMENT OF WATER UTILITY FACILITIES

| CHARACTER OF RESPONSE | | | |
|-------------------------|---------------------|--|---|
| Facilities | Damage | Blast and Shock | Thermal Rad. Ionizing Rad. |
| STRUCTURE | | | |
| d) Service pipe | Light (1-2 psi) | Numerous leaks and breaks. Loss of water until service area shut-off. | Fire damage to service pipe. |
| | Moderate (2-6 psi) | Debris problem delay shut-offs due to valve being covered. | |
| | Severe | Extensive fire damage in pipes. | |
| | (6 psi up) | Breaks and leaks on services. | |
| POWER | | | |
| a) Normal power supply | Light (2 psi) | Power service temporary outage. | 1) Damage to power appurtenance. 2) Fire through electric short circuit. 3) Loss of fuel. Fire damage to standby power supply facility. Normally not considered |
| | Moderate (3 psi) | Power service outage up to one month. | |
| | Severe (4 psi) | Power service outage more than one month. Underground electric circuit little affected. Collapse of high voltage suspension tower. | |
| | Light (0.5-1.0 psi) | Wires and other appurtenances damaged. | |
| b) Standby power supply | Moderate (3-4 psi) | Damage to gas storage tank and other appurtenances. | Normally not considered |
| | Severe (10 psi up) | Heavy machine survives without substantial damage. Appurtenances either broken or damaged seriously. | |

EXAMPLE OF A UTILITY ASSESSMENT

Table IV is an example of a vulnerability assessment of a municipal water utility with the following characteristics.

- 1) Population served: 150,000
- 2) Average daily consumption: 30 mgd
- 3) Area served: 25 sq miles
- 4) Pressure Zones: Three major pressure zones are provided through local topographic condition in the service area.
- 5) Water sources: Surface water (local): 15% of total supply is produced by 2 local streams.

Surface water (imported): 55% of total supply is purchased from other water districts via long transmission line.

Ground water (local): 30% of total supply is produced by 12 deep wells located within service area.

- 6) Reservoirs: 17 covered reservoirs ranging in size from 0.9 mg to 50 mg are at various locations in the service area and provide total storage capacity of 100 mg.
- 7) Pumping facilities: There are 34 pumping stations in the system - 12 for deep well water pumping and the other 22 for booster pumping. No. 1 well is installed with submersible pump while turbine pumps are used for other wells. Electric power is used at all pumping stations except at the No. 3 well which is driven by a 40 HP gasoline engine.

The assessment can and should be simplified by eliminating from the study most of the smaller or non-critical portions of the system.

The first step in the assessment is to list the facilities to be checked. For each type of facility involved a list of items to be field checked is made. A tabulation similar to Table IV is then made and the estimated response of each of the facilities is noted.

The tabulated data is then studied to determine the most vulnerable facilities and the relative importance of the various items is considered. In this study the following conclusions were made:

TABLE IV
EXAMPLE OF VULNERABILITY ASSESSMENT OF WATER UTILITY

| Facilities | Blast and Shock Effect | | | Thermal Radiation Effect | Ionizing Radiation Effect | Corrective Measures |
|--|------------------------|---------------------------|---|------------------------------------|-------------------------------------|---|
| | 0.5 psi | 3 psi | 5 psi | | | |
| <u>SOURCES</u> | | | | | | |
| <u>Ground Water</u> | | | | | | |
| (Deep well Nos.1,2,3,4,5) | | | | | | |
| a) Well | No effect | No effect | No effect | No effect | No effect | |
| b) Submersible motor and pump (No. 1) | Ditto | Ditto | Ditto | Ditto | Ditto | |
| c) Deep well turbine pump (Nos.2,3,4,5) | Ditto | Ditto | Ditto | Ditto | Ditto | |
| d) Motor (above ground) (Nos.2,3,4,5) | Insignificant | Moderate damage | Damaged Extensively. | Insignificant | Needs decontamination before access | Needs standby power. Provide facilities for change-over to gasoline operation. |
| e) Electric power service (Nos. 1,2,4,5) | Temporary Outage | Outage to 30 days | Prolonged outage | Ditto | Ditto | |
| f) Natural gas power service (No. 3) | No effect | Gas pressure lowered. | Gas delivery outage to 30 days | Ditto | Ditto | |
| g) Engine Control (No. 3) | No effect | Insignificant | Minor damage | Ditto | Ditto | |
| h) Switch gear (Nos.1,2,4,5) | Insignificant | Moderate to severe damage | Prolonged outage. | Ditto | Ditto | |
| i) Appliances (Valves & gages, etc.) (Nos.1,2,3,4,5) | No effect | Insignificant | Insignificant | Ditto | Ditto | |
| j) Superstructure (Nos. 1,2,4,5) | Minor damage | Moderate damage | Extensive damage | Ditto | Ditto | |
| k) R.C. Superstructure | No effect | Insignificant | Damage to right angle drive and drive shaft | Fair protection within engine room | Place shield over drive shaft | |
| <u>Surface Water</u> | | | | | | |
| (Stream Nos. 1 and 2) | | | | | | |
| a) Diversion structure (Nos. 1 and 2) | No effect | Insignificant | Minor damage to structure | Fire on watershed. | Contamination by fallout. | |

TABLE IV

EXAMPLE OF VULNERABILITY ASSESSMENT OF WATER UTILITY

| Facilities | Blast and Shock Effect | | | Thermal Radiation Effect | Ionizing Radiation Effect | Corrective Measures |
|--|------------------------|-----------------------------|--|--------------------------|--|--|
| | 0.5 psi | 3 psi | 5 psi | | | |
| <u>SOURCES(Continued)</u> | | | | | | |
| <u>Surface Water</u> | | | | | | |
| b) Intake structure screen (Nos. 1 & 2) | No effect | Insignificant | Clogging by debris. | | | |
| c) Power service (No. 1) | Temporary outage. | Probable outage to 30 days. | Prolonged outage. | | | |
| d) Tunnel (No. 2) | No effect | Insignificant | Damage at openings. | | | |
| <u>Imported Surface Water</u> | | | | | | |
| a) Service connection (underground manhole) | No effect | No effect | No effect | No effect | No effect | Emergency source required. |
| b) Control and metering (automatic) facility | Insignificant | Outage due to power failure | Moderate damage | No effect | No effect | |
| <u>TREATMENT PROCESS</u> | | | | | | |
| <u>Disinfection Facility</u> | | | | | | |
| a) Chlorinator and tubing | Minor damage | Minor damage but repairable | Severe damage but major repairs necessary. | Fire damage | Radioactive contamination | Shield exposed tubing and chlorinator |
| b) Chlorine container | Insignificant | Minor damage | Severe damage | Explosive to fire | Insignificant | Shield |
| c) Power supply | Temporary outage | Outage to 30 days | Prolonged power outage | Insignificant | Insignificant | |
| d) Structure | Light damage | Moderate damage | Moderate damage | Insignificant | Insignificant | |
| <u>Laboratory Control</u> | | | | | | |
| a) Equipment | Minor damage | Severe damage | Severe damage | Fire damage | Radiation contamination of laboratory equipment and chemicals. | Provide alternate lab. facilities in protected location. |
| b) Chemical supply | Ditto | Ditto | Ditto | | | |
| c) Glassware | Ditto | Ditto | Ditto | | | |
| d) Stockpiles | Ditto | Ditto | Ditto | | | |
| e) Utilities (gas,water, electricity) | Ditto | Moderate damage | Ditto | | | |
| f) Structure | Light damage | Ditto | Ditto | | | |

TABLE IV

EXAMPLE OF VULNERABILITY ASSESSMENT OF WATER UTILITY

| Facilities | Blast and Shock Effect | | | Thermal Radiation Effect | Ionizing Radiation Effect | Corrective Measures |
|--|-----------------------------|---|---------------------------------------|---|---|--------------------------------|
| | 0.5 psi | 3 psi | 5 psi | | | |
| WATER STORAGE | | | | | | |
| Reservoirs Nos. 1,2,3,4, 5,6,7,8,9 | | | | | | |
| a) Wood frame roof structure (Nos. 1,2,3,4,5, 6 and 9) | Insignificant | Partial collapse | Complete collapse | Fire damage to roof structure possible. No effect | Radioactive contamination of exposed water. No effect | |
| b) R.C. roof structure (Nos. 7 and 8) | No effect | Insignificant | Insignificant | No effect | No effect | |
| c) Corrugated iron tank structure (Nos. 1,2, 3,4,5,6) | Insignificant | Insignificant | Insignificant | No effect | No effect | |
| d) R.C. reservoir structure (Nos. 7 and 8) | No effect | Ditto | Ditto | Ditto | Ditto | |
| e) Steel tank structure (No. 9) | Ditto | Ditto | Ditto | Ditto | Ditto | |
| f) Power service (Nos. 7,8, and 9) | Temporary outage | Outage to 30 days | Prolonged outage | Ditto | Ditto | |
| g) Valving & control facilities (Nos.1,2,3,4,5,6,8,9) | Insignificant | Insignificant | Insignificant | Ditto | Ditto | |
| h) Valving & control facility (No. 7) | Temporary outage. No effect | Power & automatic control outage. Insignificant | Prolonged power outage. Insignificant | No effect | No effect | |
| i) Inlet and outlet | | | | No effect | No effect | |
| PUMPING FACILITY | | | | | | |
| Pumping Stations | | | | | | |
| Nos. 1,2,3,4 | | | | | | |
| a) Power supply (Nos. 1,2,3,4) | Temporary outage | Outage to 30 days | Prolonged outage | Fire damage | No effect | Provide auxiliary power source |
| b) Switch gear (Nos. 1,2,3,4) | Insignificant | Minor damage | Severe damage | Insignificant | No effect | |
| c) Apparatuses(valves, gates, etc.) (Nos. 1,2,3,4) | Insignificant | Recorder & automatic control inoperative. (no. 2) | Severe damage | Insignificant | No effect | |

TABLE IV
EXAMPLE OF VULNERABILITY ASSESSMENT OF WATER UTILITY

| Facilities | Blast and Shock Effect | | | Thermal Radiation Effect | Ionizing Radiation Effect | Corrective Measures |
|--------------------------------------|------------------------|---|---|--------------------------|---------------------------|---|
| | 0.5 psi | 3 psi | 5 psi | | | |
| POURING FACILITIES (continued) | | | | | | |
| Pumping Stations | | | | | | |
| Nos. 1,2,3,4 | | | | | | |
| d) Motor (Nos. 1,2,3,4) | Insignificant | Minor damage | Severe damage | Insignificant | No effect | Replace frame building |
| e) Pump (Nos.1,2,3,4) | Insignificant | Insignificant | Insignificant | Insignificant | No effect | |
| f) Pump station (Nos.1,2,3,4) | Insignificant | Roof collapses (No. 1). Insignificant (2,3,4) | Roof collapses (No. 1) Concrete roof cracks (2,3,4) | Insignificant | No effect | |
| g) Connection to main pipe | Insignificant | Insignificant | Insignificant | Insignificant | No effect | |
| TRANSMISSION AND DISTRIBUTION SYSTEM | | | | | | |
| a) Piping (exposed) | No effect | Insignificant | Minor damage | No effect | No effect | Replace exposed piping with steel pipe. |
| b) Piping (underground) | No effect | Insignificant | No effect | No effect | No effect | |
| c) Appurtenances | | | | | | |
| Valving | No effect | Insignificant | Insignificant | No effect | No effect | |
| Air valve | No effect | Insignificant | Minor damage | No effect | No effect | No effect |
| Hydrants | Insignificant | A few breaks | Numerous breaks | No effect | No effect | No effect |
| Service pipe | Light damage | Extensive breaks | Loss of water pressure | Fire damage | No effect | No effect |

Source Supplies

- 1) Wells - Although deep wells may very well withstand nuclear blast with high overpressure, the electric power supply is vulnerable and service may fail because of a lack of power. Well No. 3, however, will probably continue in operation as it is gas engine driven with standby gasoline carburation and is housed in a blast resistant building.
- 2) Imported Aqueduct Source - The aqueduct and its service take-offs are relatively invulnerable, but a study of the source facilities indicated that prolonged aqueduct outage should be anticipated following nuclear attack.
- 3) Surface Streams - Facilities are relatively invulnerable to blast, but radiation and thermal effect (watershed fires) may prevent use.

The conclusion reached on source supplies was that Well No. 3 offered the only dependable source of water following nuclear attack. This well, with a capacity of 1800 gpm, will furnish water to the highest pressure system, and will provide at least the minimum amount of water, 10 gpd, for all the surviving population during the postattack period.

A second well source similarly hardened would be desirable.

Storage

Reservoirs were found to be relatively invulnerable except that the roofs of 6 reservoirs with a total storage capacity of approximately 52 million gallons would probably collapse. However, the concrete roofs of two reservoirs having a total storage of 52 million gallons should remain intact.

It is concluded that the vulnerability of the reservoir storage will be only affected by the possible contamination by fallout in the water in those reservoirs where the roofs have collapsed, and this should not be a significant radiation ingestion hazard.

Booster Pumping System

The booster pumping facilities are vulnerable through power source failure. Reliable standby power sources are necessary to improve this condition to provide at least minimum booster pumping service. Poles, lines, etc., have higher blast resistance than most buildings.

Transmission and Distribution System

The transmission system is well protected. The distribution system piping is not vulnerable except for appurtenances such as above ground fire hydrants and house piping connections. The major problem expected is the

rapid loss of stored water through leaks developing within consumers' property when the service piping in homes and buildings is damaged.

Miscellaneous Facilities

The laboratory is extremely vulnerable and standby field laboratory facilities must be provided in well protected locations.

The warehouse and equipment yards are somewhat vulnerable but sufficiently dispersed to be at least partially resistant to attack.

Communication equipment is reliable with at least 10 mobile radio units available in case of failure of the communication control center.

Shelter facilities for personnel are barely adequate and should be improved.

REFERENCES

- (1) The Effect of Nuclear Weapons, Department of Defense and Atomic Energy Commission, Washington D.C., April 1962.
- (2) Handbook for Radiological Monitors, Department of Defense, Office of Civil Defense, Booklet MP-15, Washington D.C., April 1963.
- (3) Handbook for Radiological Monitors, Department of Defense, Office of Civil Defense, Booklet PG-E-5.9, Washington D.C., April 1963.

CHAPTER IV

PROTECTIVE MEASURES

INTRODUCTION

The purpose of this chapter is to present principles for the protection of personnel and water facilities from nuclear explosions. A large number of water systems in the United States would be outside the limits of blast or heat effects of any nuclear attack within the scope of present military estimates, but nearly all would be exposed to hazardous radiation effects of radioactive fallout which may cover wide and unpredictable areas as shown in Figure 17. The need for "hardening" planning to provide blast and thermal protection for water systems located near critical target areas will be discussed, but the major emphasis will be placed on human survival especially protection from radioactive fallout.

FALLOUT PROTECTION

The purpose of fallout protection is to provide adequate construction, equipment and procedures so as to protect not only personnel, but key operating areas, and also to provide for removal of fallout from exterior surfaces with minimum difficulty so as to facilitate recovery of the waterworks.

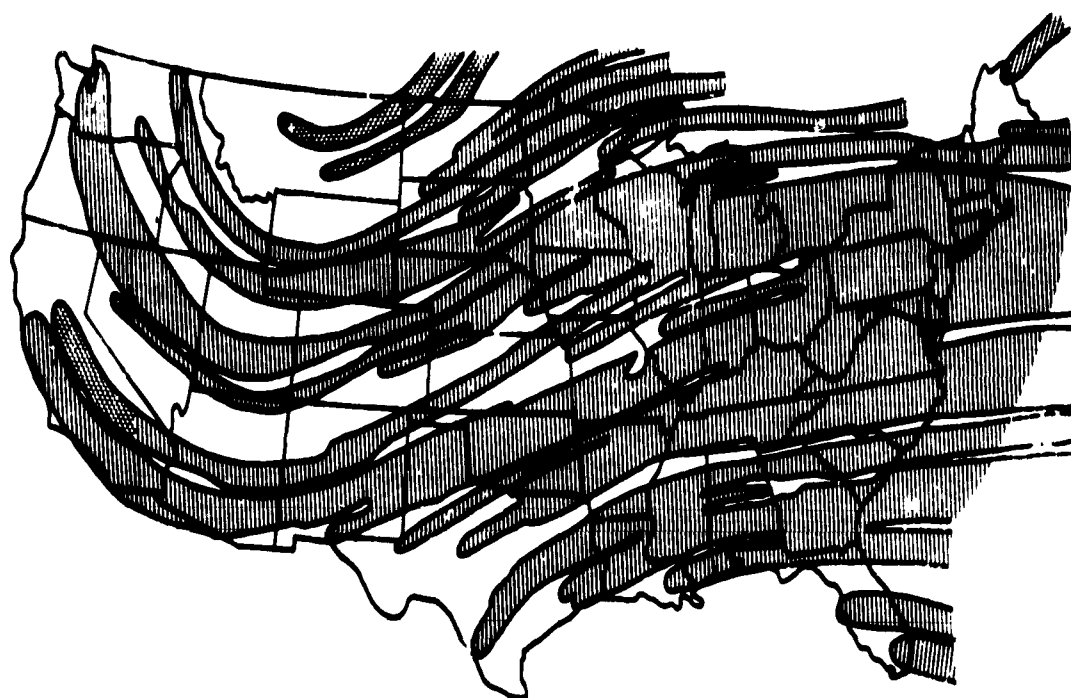
Personnel Protection

Radiation protection measures are based on the assumption that all radiation exposure is harmful. However, experience and research have shown that if exposure is kept below a certain level, medical care will not be required for the majority of the people. Few people get sick who have been exposed to 100 roentgens or less. As the exposure dose increases, the severity of effects will increase. However, the effects on individuals exposed to the same dose will vary widely. Table I may be used to estimate short-term effects on humans of external gamma exposures of less than four days.

In considering protection against the three types of radiation associated with fallout material, protection against gamma radiation is of primary importance because of its great penetrating power, similar to but more potent than x-rays. Alpha and beta radiation are relatively easy to shield against as shown in Figure 18. Gamma radiation, however, can require considerable amounts of dense materials or distance between persons and the radiation source in order to prevent damage.



Fallout areas at 1 hour after detonation



Fallout areas at 24 hours after detonation

Figure 17. — DISTRIBUTION OF EARLY FALLOUT FROM ASSUMED ATTACK

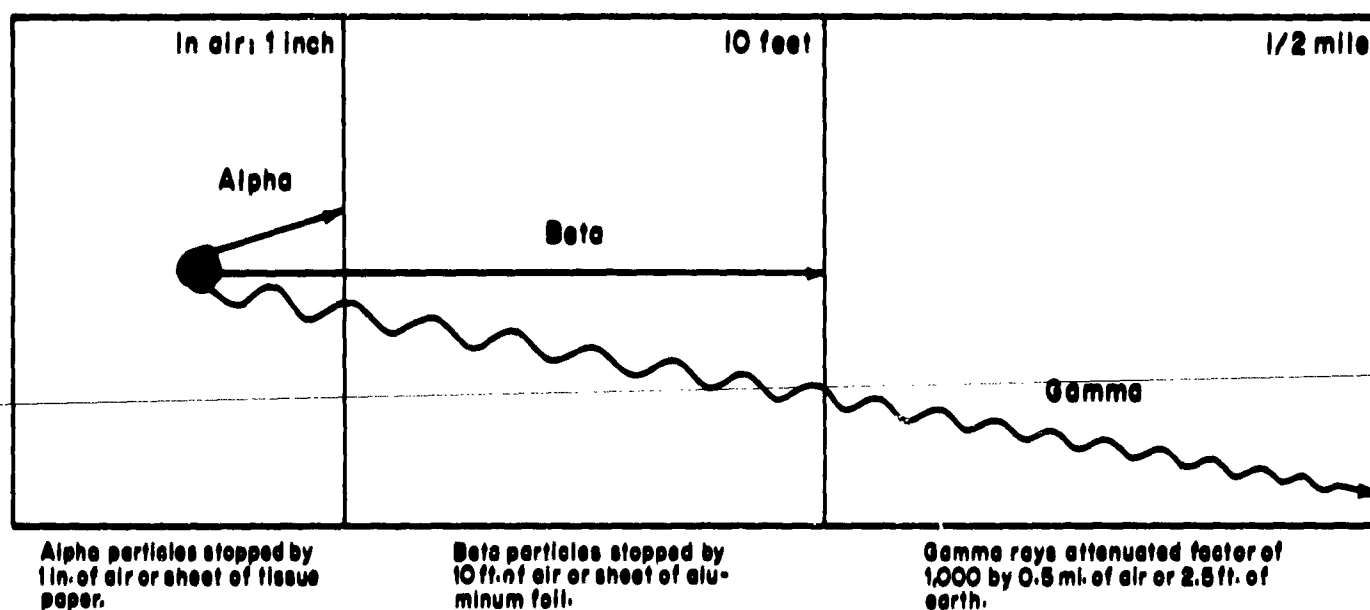


Figure 18. — COMPARISON OF PENETRATING POWER OF ALPHA, BETA, AND GAMMA RADIATION

Shielding Protection

Protection from the effects of fallout gamma radiation may be achieved in two ways. One method is to place a barrier or shielding material between the fallout field and the person. The second is to increase the distance of the person from the fallout field. This is termed distance or geometry shielding. In most cases, it is necessary to consider the combined effects of both barrier and geometry shielding to determine the effectiveness of a shelter. The protection provided by shielding in a typical filter building is shown in Figure 19. Gamma rays are absorbed to some extent when they pass through any building materials. The shielding effects of various kinds of walls and roofs are related to the thickness and density of the material. A greater thickness of a less dense substance (wood) than one of high density (metal) is required to attenuate the radiations by a specified amount.

The term "protection factor" expresses the relative reduction in the amount of radiation that would be received in the protected location compared to the amount it would receive if it were unprotected. For convenience of calculation, the reciprocal of the protection factor, called the "reduction factor", is used. Reduction factors, expressed as decimals, can be added when combining the effects of fallout on the roof over the area of interest (roof contribution) and fallout on the ground surrounding this area (ground contribution). For example, the roof contribution on the operating floor of a filter building in Figure 19 may be 0.015 and the ground contribution at this point 0.01. The sum of these, 0.025, would be the total reduction factor, and the protection factor would be the reciprocal of 0.025, or 40. In the pipe gallery, the greater mass thickness of reinforced concrete walls, operating floor, filter sand and water may improve the total reduction factor to 0.0005, a protection factor of 2,000.

In its passage through the atmosphere, gamma radiation, like thermal radiation, is scattered by particles present in the air. Even though most of the radiation will be received along a direct "line of sight" from the source, scattering will cause a certain portion to arrive from oblique directions. Consequently, some shielding must be provided on all sides of an individual in order to furnish adequate protection.

Distance Protection

In addition to the attenuation afforded by direct shielding, gamma rays diminish with increased distance from the radiation source. For a uniformly distributed source, such as a fallout field, the area nearest the receiver contributes the most radiation. For example, the attenuation at 3 feet above the center of a decontaminated circle with 50-foot radius is about 0.48. However, to obtain further significant attenuation, the radius of the cleaned or decontaminated surface must be increased markedly. If, in order to utilize a facility in a contaminated area, it is necessary to reduce the radiation dose rate to one-tenth the original intensity, an area 600 feet in radius around the facility must be cleared.

| | | | |
|---------------------|---|---------------------------|--------------------------|
| | | <u>Operating Floor</u> | <u>Pipe Gallery</u> |
| REDUCTION FACTOR = | $\frac{\text{Radiation level in shelter}}{\text{Radiation level outdoors}}$ | $\frac{100}{4000} = .025$ | $\frac{2}{4000} = .0005$ |
| PROTECTION FACTOR = | $\frac{1}{\text{Reduction Factor}}$ | 40 | 2000 |

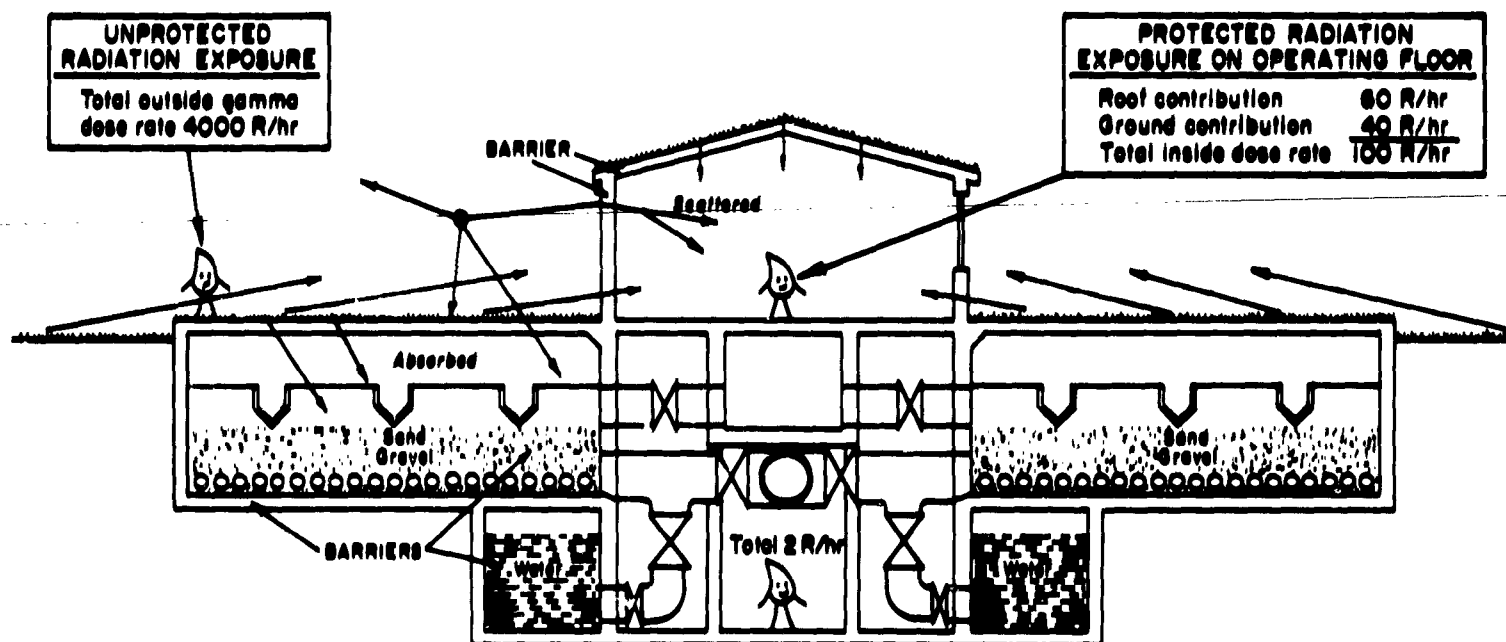


Figure 19.— SHIELDING AT TWO LOCATIONS IN FILTER BUILDING

Radiological Monitoring

An important part of the program of protecting personnel from radiation hazards is the provision of adequate monitoring facilities, trained personnel and tested procedures. Personnel must be aware of the extent and location of such hazards and have the knowledge to minimize the danger.

Trained monitors will be required to furnish data on radiation dose rates essential for the assessment of fallout hazards. Waterworks should have radiological detection instruments and two or more personnel with monitoring capabilities assigned to each of its major production and distribution facilities which could function as an emergency fallout shelter.

During the early postattack period, radiological information needed by shelter occupants will require monitoring of areas in the shelter to locate the best shielded areas for use when dose rates are high. When dose rates have decreased to the extent that limited outside activities can be performed, monitors will support emergency recovery operations. Postattack operations will require measurement of dose rates in the shelter as well as estimation of permissible stay-time outside the shelter. Radiation exposure records should be kept on all water system personnel.

There is a continuing need for monitoring through the period of gradual relaxation of sheltered living even after gamma radiation no longer seriously restricts unsheltered living. During the recovery period, the need for frequent reports of monitored data becomes less urgent but the requirement for monitoring of specific areas and facilities, in support of large-scale decontamination operations increases. Monitoring is required until all radiation hazards are determined to be insignificant.

The Handbook for Radiological Monitors provides basic information the monitor must have to carry out his duties of detection, measurement, and reporting of radiation. While it is primarily intended for use as an operations manual in conducting radiological monitoring, it is also useful as a student manual in monitor training. It may be obtained through your local civil defense organization by citing the title and the Federal Civil Defense Guide number FG-E-5.9.

Control of Exposure

Monitors are responsible for limiting the exposure and maintaining the personal radiation exposure records for themselves and all emergency operations personnel at their station. Radiation exposures are likely to lack a uniform pattern. After a period of low exposure, an operational mission may require a high exposure. This may be followed by several days of relatively low exposure before the situation requires an additional high exposure. The only reliable method of keeping track of variable exposures is through the use of personal dosimeters and the keeping of complete exposure records.

All but the most important water system and survival operations should be postponed as long as practical to take advantage of the decay of fallout. In carrying out high priority tasks exposures should, where practicable, be more or less distributed among operations personnel.

Nomograms as shown in Figures 14 and 15 based on theoretical fallout radiation decay characteristics, may be used for rough estimates of future dose rates and radiation exposures that might be expected in performing necessary tasks outside the shelter. However, when fallout from several nuclear weapons detonated more than 24 hours apart is deposited in an area, the decay rate may differ markedly from the assumed decay rate. Calculation of future dose rates must not be made until dose rates have been decreasing for at least 2-3 hours, and forecasts should be made for periods no further in the future than the length of time the radiation levels have been observed to decrease.

Missions must not be started until monitoring indicates that predicted conditions actually prevail. At least one survey meter and one or more dosimeter will be carried by the mission crew and these will be read periodically to assure limiting the dose to the established value. Generally, outside missions should be short, not to exceed three hours.

The "Dose Rate" and "Entry Time - Stay Time - Total Dose" nomograms shown on Figures 14 and 15 respectively are especially useful for finding the dose rate and earliest entry time into an area to perform a job requiring a known stay time. Their use will permit an earlier scheduling of the mission than to assume that the outside radiation dose rate remains constant (no decay) from the time of entry into the radiation field until the return to shelter. Under the latter assumption, the total dose equals the dose rate at time of entry multiplied by the length of time stayed on the mission. If the above nomogram is not available, then the time for beginning the mission should be delayed until the entry dose rate, r/hr, outside shelter has decreased to a value determined by $\frac{\text{Dose (roentgen) allowed for mission}}{\text{Estimated Stay Time (hours) for mission}}$.

The guide shown in Table V may be useful for estimating the permissible activities outside shelter when the dose rates inside and outside of the shelter are known. The dose rate inside a shelter can be estimated, using dose rate outside shelter and protection factor.

Contamination Control Inside Shelter

During fallout deposition, all windows, doors, and non-vital vents in sheltered locations should be closed to minimize the contamination entering the shelter. These and other protective measures such as covering should be applied to vehicles because the radiation dose rate, while in a vehicle that has been sheltered during the time of fallout, is only one-half of the dose rate of a vehicle that has received fallout in the open.

TABLE V
GUIDE TO PERMISSIBLE ACTIVITIES

| Outside dose rate in r/hr at (H+1) at (H+2 days) | | <u>Permissible Activities</u> |
|--|---------------------|--|
| Greater than 10,000 | Greater than 100 | Outdoor activity of more than a few minutes may result in sickness or death. Occasions which might call for outside activity are: (1) risk of death or serious injury in present shelter from fire, collapse, thirst, etc., and (2) present shelter is greatly inadequate and better shelter is known to be only a few minutes away. |
| 1,000 to 10,000 | 10 to 100 | Time outside of shelter should be held to few minutes and limited to those few activities that cannot be postponed. |
| 200 to 1,000 | 2 to 10 | Periods of less than an hour per day of outdoor activity are acceptable for the most essential purposes. Shelter occupants should rotate outdoor tasks to distribute exposures. |
| 50 to 200 | 0.5 to 2 | Outdoor activity (up to a few hours per day) is acceptable for essential purposes such as: fire fighting, police action, rescue, repair, securing necessary food, water, medicine and blankets, important communication, disposal of waste, exercise and obtaining fresh air. Eat, sleep, and carry on all other activities in the best available shelter. |
| Less than 50 | Less than 0.5 | No special precautions are necessary for operational activities. Keep fallout from contaminating people. Sleep in the shelter. |
| Less than 1 | Less than 0.001 | Resume normal activities. Continue recovery and decontamination operations. |

NOTE:

1. This table is based on a shelter protection factor of 200 to keep 4 day total exposure dose received to 200 roentgens or less.

2. The time outside shelter is based on accumulated dose inside shelter plus dose to be received outside shelter calculated from Figures 12 to 13 or by the formula Dose (roentgen) allowed for mission = Entry Dose rate (r/hr) x Estimated Stay Time (hour) for mission. Total accumulated dose received outside and inside shelter of 200 roentgens should not be exceeded without careful consideration.

Before entering the shelter area persons arriving at a shelter should stamp their feet and shake their clothing to remove contamination.

Contaminated portions of the skin and hair may be washed, brushed, or wiped thoroughly, but do not injure the skin. If the civil defense radiological instrument CD V-700 can be used then the radiation field is inconsequential in the shelter.

Contamination Control Outside Shelter

Clothing will not protect personnel from gamma radiation but will prevent most airborne contamination from depositing on the skin, and thereby reduce the need for extensive washing or scrubbing of the body for prevention of beta burns. Most closely woven clothing is satisfactory when the emergency operators are instructed to:

1. Wear adequate clothing and cover as much of the body as practicable. Wear boots or rubber galoshes, if available. Tie pant cuffs over them to avoid possible contamination of feet and ankles.
2. Avoid highly contaminated areas whenever possible. Puddles and very dusty areas where contamination is more probable should also be avoided.

Food and Water

Food and water should be protected from fallout as far as is practicable. If it is suspected that unopened food containers are contaminated, they should be washed or brushed prior to opening and removal of the contents. Food properly removed from such containers will be safe for consumption.

Water in covered containers and underground sources will be safe. Before the arrival of fallout, open supplies of water such as cisterns, open wells, etc. should be covered. No food and water suspected of contamination should be destroyed or thrown away.

Do not discard contaminated food or water. It should be decontaminated and rechecked, or placed in storage and rechecked at a later date for possible consumption after the contamination has decreased through radioactive decay. Foods such as fruits and vegetables could be decontaminated by washing, brushing, or peeling. Water which is heavily contaminated might be improved by filtering, or by allowing any particles to settle out. If only contaminated food or water is available, the monitor should recommend that supplies with the smallest amount of contamination be used first.

BUILDING PROTECTIVE CONSTRUCTION

Reduction of Fallout Deposition and Retention

The protection which a facility affords can be improved by making it more difficult for fallout material to be deposited and to remain on its

exterior surfaces. The vulnerability of buildings to fallout depends on (a) general orientation of exterior surfaces which determine the air flow pattern around buildings and affect the drainage and weathering of fallout material from surfaces; and (b) the detailed surface conditions which influence retention of contaminant.

Facilitation of Fallout Removal

Even though buildings and water facilities are designed to reduce fallout retention, a certain amount will be deposited and retained. Such deposits of contamination must be physically removed or shielded in place. The principal ways to rid a surface of fallout are:

1. Washing fallout deposits off the surfaces and into gutters and drainage systems with firehoses and street flushers.
2. Picking up and collecting fallout material with street sweepers.
3. Burying fallout in place with plows or new earth fill.
4. Removing soil contaminated by fallout with earthmoving equipment.

If water is to be used as the decontaminating media, the surfaces should be smooth enough to dislodge fallout particles readily, and the slope and cross-sectional shape of drainage channels should provide a high velocity flow for efficient transport of the suspended particles to storm drains or sewers. An adequate slope to roofs and the areas next to buildings is an important feature of a well-planned drainage system.

Rainfall is capable of decontaminating roofs and exterior surfaces. However, it may not be very effective unless the drainage conditions for removal of runoff water are designed with this in mind.

Planning for fallout removal must include accessibility and services. If firehosing is to be employed for decontaminating roofs, exterior access to the building roof should be provided along with built-in headers to allow hose connections at roof level so as to eliminate long runs of hoses. Operation of motorized flushing equipment, street sweepers, plows, trucks, and other large rigs will be facilitated by advance planning of spacings between buildings, service poles, hydrants, fences and other obstructions. Sloping ramps may be helpful for moving heavy equipment to different operating levels. In all cases, paving must be strong enough to bear rolling stock.

Although a number of effective decontamination methods are applicable, those employing water are generally more available. For this reason, in some areas the demands on the water supply for decontamination may rival those experienced when fighting fires. Planning for an emergency network of independent water systems is an important protective measure. This will be discussed in Chapter VII.

Fallout Protective Construction -- New Buildings

Many new water facilities can be made to furnish greater fallout protection by the timely application of the principles of shielding and distance protection discussed in previous section. When these principles are considered early in the planning of new construction the degree of fallout protection may be greatly improved at minimal additional cost. It is beyond the scope of this manual to present a detailed guide for design of protective structures.

Fallout Shelters for Water Utilization

Fallout protection should be provided in or near each essential water production, treatment, or distribution facility requiring full time or even part time operators for control and maintenance of the equipment. The normal travel time from the nearest shelter to the facility should not be excessive in any case. At pumping plants and reservoirs, the underground or underwater structures housing pumps, valves, or pressure regulators are often sufficiently shielded by concrete walls, earth and/or water to provide a good protective shelter for utility operators and their families. As shown in Figure 19, the underground pipe gallery in a large filter building will provide a spacious shelter with a high protection factor. Even in small filter plants certain locations may make excellent shelter areas. Shelters should be specifically planned for new structures.

Careful analysis of the barrier shielding effect of filter beds, water, concrete walls, and metals in valves, pipes, etc. will enable utility management to predetermine the best locations for total shielding from exterior radiation. A minimum protection factor of 100 is desirable for any structure intended to be occupied as a fallout shelter, and shelter facilities near critical target areas should have higher protection factors. Underground or underwater structures with a complete envelope of shielding equivalent to more than 3 feet of earth will have a protection factor of about 2,000. In making this analysis, the presence of openings in walls or poorly shielded components must not be ignored because the net protection factor can be decreased greatly by the presence of voids which will leak excessive amounts of incident gamma radiation.

The "core" concept in shelter design may be useful for reducing the cost of fallout protection in new or existing utility structures. The "core" shelter is a relatively small area with a high protection factor, surrounded by a larger area that has a lower protection factor. During the critical period when outside radiation dose rates are high, occupants would remain in the "core" shelter, with minimum space and ventilation. Later, when fallout decay lowers the outside dose rate, the larger shelter area, with better living conditions, could be used.

Human Needs in Shelter

The minimal space and equipment requirements for a shelter must necessarily be based on austerity or "survival" limits that the shelter occupants

can endure for a period of several days to two weeks. For design purposes, assume 2-4 days of continuous occupancy in maximum shielded or "core" area, then 2 weeks until day-long freedom is possible. Then the following criteria may be used:

1. Gross floor area of 15 sq ft per occupant includes such items as columns, fixed equipment, and storage space for shelter supplies. The minimum net floor area allowance per person is 10 sq ft except when using the core shelter principle. In that case, the net area may be reduced to 8 sq ft per person for short-term occupancy. Table VI is given to aid in planning optimum use of shelter.

TABLE VI
FACTORS FOR SHELTER CAPACITY PLANNING

| Activity | Floor Space Required | Remarks |
|--------------------------|----------------------|--------------------------------------|
| Sleeping in cots | 30 sq ft | Includes aisle space |
| Sleeping in double bunks | 15 | Includes aisle space |
| Sleeping in triple bunks | 10 | Includes aisle space |
| Sitting | 8 | Includes aisle space |
| Walking | | Use aisle space |
| Storage | 2 | Includes space for food, bunks, etc. |
| Fixed equipment | As required | |

2. The ceiling height should be 7 ft for walking areas; 9 ft for tiered bunk sleeping; 5 ft for seated adult; and 4 ft for crawl in.

3. Ventilation equivalent to 3 cfm of fresh air per person is required to control the carbon dioxide concentration below 3 percent by volume. Oxygen supply is generally not a critical factor when the carbon dioxide concentration is controlled. A combination of high temperature and high humidity may be hazardous, and more fresh air may be needed to keep the effective temperature below 85°F. If no mechanical ventilation is available, a net volume of 500 cu ft per person may be used for estimating shelter capacity. If equipment is available for mechanical ventilation at rates of

less than 3 cfm of fresh air per person, with occupancy estimated on the basis of floor area, the net volume of space required per person may be determined from Table VII.

TABLE VII
RELATION OF SPACE REQUIREMENTS TO VENTILATION

| Rate of air change (minutes) ¹ | Volume of Space required per person |
|--|---|
| | cu ft |
| 1,000+ | 500 |
| 600 | 450 |
| 400 | 400 |
| 200 | 300 |
| 100 | 200 |
| 60 | 150 |
| 35 | 100 |
| 22 | 65 |

1. Computed as the ratio $\frac{\text{Net volume of space (cu ft)}}{\text{Fresh air supply (cfm)}}$

4. A standby engine-generator set should be available in water utility shelters to provide electric power for lights (5 foot-candles), fans or ventilation equipment, etc. The capacity may range from one to ten kilowatts per 100 occupants depending on the actual load.

5. Shelters should be stocked with food, emergency drinking water, communication equipments, radiological monitoring instruments, first aid supplies, blankets, and first aid, medical and sanitation handbooks. Storage of food providing about 800-1,000 calories per day per person will take two cu ft per person for two weeks, or one cu ft if dry rations are stored. Seven gallons of water per person per two weeks should be stored in closed containers to keep it dust free. Covered roof tanks, service mains, wells, and hot water tanks will normally keep water safe to drink in an emergency.

6. Sanitation requirements for large group shelters include one flush type or chemical toilet per 70 occupants plus normal facilities available in other parts of the building.

An important aspect of shelter operation relates to the policies concerning use of the facility by the water system operation and maintenance crews and their families. When a major disaster strikes, there is a strong tendency for men to look to the safety of their families first, and to their job and community responsibilities second. To focus these loyalties to a common end, a number of water supply systems, and other utilities, are adopting a policy of inviting the families of operating personnel to share shelter space at or adjacent to the critical facilities which must, at any cost, be continued in service during an emergency. Details concerning the responsibilities of employer and employee for stocking emergency food and other supplies may vary considerably, but this policy would seem to afford the greatest assurance of having experienced crews available for postattack recovery and operation of the water system.

BLAST AND THERMAL PROTECTION

Although personnel protection from a nuclear burst is largely considered in terms of fallout shelter rather than blast or thermal radiation shelters, the latter types of protection should not be ignored. All reasonable measures should be taken to make the fallout shelter as resistant to blast and thermal radiation as possible.

Blast Protection

Injury to individuals both inside and outside a structure may occur because of the blast damage to that structure. Persons in the interior of the building can be injured and trapped by collapse and fire, and those outside can be hurt by flying debris. Therefore, an important aspect of protection is an understanding of the relative ability of different structures to withstand damage from nuclear weapon blast. For office-type and residential buildings, the extent of destruction is mainly dependent on peak overpressure, and an approximate correlation between the overpressure and the expected physical damage is given in Figure 6, Chapter II.

Even though it is impractical to construct aboveground conventional buildings that will resist overpressure greater than 25 psi, the blast resistance of any structure can be increased somewhat without adding seriously to its cost. Sturdy connections between beams and columns, such as are commonly used in earthquake-resistant design, and the extensive use of bracing will generally increase the strength of the structure. Walls of reinforced concrete, which also contain the frame, will give a structure of maximum blast resistance.

Essential features of blast-resistant shelters are structural strength to resist blast loads to the selected overpressure level, an access door of corresponding strength, a protected ventilation system to permit occupancy

of the shelter until fires have subsided, and adequate nuclear radiation shielding. Additional data on blast-resistant structural design is available in references (6) and (7).

Where a blast-resistant shelter is not available, protection should be sought in the strongest building that is accessible. Above ground, the safest locations are generally near, but not against, walls and away from doors and windows. Even if there is no prior warning of a nuclear attack and the first indication is the flash of light, there may still be time to take some protective action against the effects of blast since the blast wave travels at about the speed of sound.

Thermal Radiation Protection

The direct effects of thermal radiation from a nuclear explosion on human beings are skin burns, "flash burns" and permanent or temporary eye damage. The thermal radiation is received in two pulses; therefore, if an individual is caught in the open or is near a window at the time of a nuclear explosion, evasive action to minimize flash burn injury should be taken before the maximum in the second pulse. Unlike the slower moving blast wave, the second thermal maximum arrives in less than one to about three seconds after the first pulse depending on the size of the weapon. Evasive action must be fast, but any opaque object interposed between the fireball and exposed skin will give some protection.

Thermal radiation is expected to start fires at considerable distances beyond the blast-damaged area. Appropriate fire control action may be directed along these lines: (a) reduction of potential ignition points, (b) shielding of flammable materials, (c) provision for rapid extinction of ignitions to prevent formation of large fires, and (d) prevention of fire spread by dispersal of buildings and other structures.

Waterworks Considerations

Consideration should be given to the extent of damage to waterworks facilities and equipment caused by blast and thermal radiation. Appropriate measures should be taken to protect waterworks facilities and equipment from blast and thermal radiation.

For protection against thermal radiation, flammable structures should be shielded by white paint, sanding, etc. Waterworks structures should be of great extent fire-resistant. Provisions should be made for fire control measures and for dispersion of water. Intake structures should be fire-resistant and should be housed in fire-resistant structures, the latter with fire-resistant materials, located in low fire risk areas and provided with fire suppression. In surface water supplies, brush and forest fires may result in watershed runoff containing increased amounts of suspended solids and possibly toxic materials from burned plants on the watershed area. In such cases, provision should be made to hold water in impoundment storage for solids to settle; minimize surface flow into intake impoundment by manipulation of upstream check dams; by-pass water containing debris; treat water to

flocculate and settle suspended material; use auxiliary treatment; select level from which water is withdrawn to deliver water of better quality; or use alternate source. Ground water sources will normally not be affected by thermal radiation.

For protection against blast and shock, available protective measures for structures can include providing greater structural strength; shielding by burial, mounding, etc.; abandoning or by-passing units; and anchoring parts that may react as missiles. Equipment can be shielded in shock resistant structures, anchored, and the structural strength of the weakest components increased. In surface water supplies, provision can be made to use an alternate intake or alternate supply; by-pass water containing excess amounts of material; use emergency improvised water treatment; or use other measures as given under thermal radiation above which are appropriate. For ground water sources, protection of the above ground facilities are of especial importance. Emergency portable power and pumping units can be invaluable. Provision should be made for water analysis after attack and treatment with portable units if necessary. Well casings should be extended above flood levels that may occur as a result of warfare.

REFERENCES

- (1) The Family Fallout Shelter, Office of Civil Defense, Booklet MP-15 Washington, D.C.
- (2) Handbook for Radiological Monitors, Department of Defense, Office of Civil Defense, FC-E-5.9 (April 1963).
- (3) Radiological Recovery of Fixed Military Installations, Departments of the Army and the Navy, TM 3-225 (April 1958).
- (4) Owen, W. L., Radiological Protective Construction, U. S. Naval Radiological Defense Laboratory, USNRDL-467, January 8, 1962.
- (5) Fallout Shelter Surveys: Guide for Architects and Engineers, OCD Document NP-10-2, National Plan Appendix Series, May 1960.
- (6) The Effects of Nuclear Weapons, Department of the Army pamphlet No. 39-3, April 1962.
- (7) Recommended Specifications for Blast-Resistant Structural Design, Department of Defense, Office of Civil Defense, Technical Report 11, Reprinted March, 1962.

CHAPTER V

POSTATTACK ASSESSMENT OF PLANT OPERATION

INTRODUCTION

Following a nuclear attack, one of the first duties of utility personnel will be the assessment and evaluation of the condition and capability of the surviving facilities, equipment and personnel. At the same time, the condition of the surviving community must be determined as it is the needs of the surviving community that are of prime importance. The assessment will begin with information received in shelters using the available communication facilities. It will be extended by reconnaissance outside the shelters as soon as it has been determined that the radioactivity is at a sufficiently low level to permit one to leave the protection of the shelter.

Part of the assessment information can be obtained during the pre-attack alert. During this period information can be transmitted to the utility control center not only on assessment of supplies, materials and personnel in each mobilization area or shelter, but on the pre-attack operations that have been accomplished since the alert was given. These are the operations that have been determined as necessary by advance planning.

In many areas it is probable that a time lag will occur between the immediate effects of the burst and fallout deposition. Actions can and should be taken during this time (30 minutes to several hours) before the shelters are entered to improve the postattack situation, i.e. putting out fires, consolidating personnel, closing critical valves, etc. This information, too, can be reported to the utility control center.

The results of the assessment will be used by waterworks management to determine what the postattack water needs are, the facilities that can be utilized and the most effective way to resume operation in the available time. The operation of water supply systems and the need for water from the systems which have experienced the effects of nuclear weapons will differ greatly from that of the pre-attack period.

The use of other civil defense agencies will be invaluable in locating water needs, sources of water and determining condition of the system. The fire control personnel will know what the needs are for fire suppression. The decontamination units will know where and in what amounts water is needed for decontamination. The public health units will know the needs for sanitary use. Other civil defense units will know the areas where there are survivors that will need water when their inshelter supply is exhausted. The water utility itself, through advance inventorying of the users will know the water users that are considered critical in time of disaster. With this information, the water utility can direct the postattack operation and recovery program accordingly.

The general purpose of this chapter is to define the nature of an emergency resulting from a nuclear attack and indicate assessment procedures. Information is provided for making a postattack assessment so that functional plans leading to the restoration of operation can be made and carried out.

GENERAL DESCRIPTION OF POSTATTACK CONDITIONS

Following a nuclear attack all or portions of the community may have structural damage, fires, fallout and/or loss of power. These conditions may be present in varying degrees, depending on the factors that have already been discussed in previous chapters.

Some areas will experience structural damage from blast and thermal radiation and also radioactive fallout. All or portions of the waterworks may well be damaged beyond repair and only those personnel who have extremely good sheltering will survive. In these areas, because of blast and shock damage as well as physical injury and loss of waterworks personnel, the application of countermeasures in recovery of water supply will require greater effort and take a longer time to accomplish. Some portions of the system will be incapable of performing their functions and may have ruptured or leaked so that the water stored in the system will have been lost. If critical valves are shut off in time, much of the critically needed water may remain in the system. The surviving personnel will have to remain in the shelters for a period of time during which the waterworks facilities must go unmanned. Automation may be of great value in keeping the system functioning. In some systems the lack of power will result quickly in an inability to supply water. The postattack assessment in areas such as this will be much more difficult. The effectiveness of the assessment will be affected by the level of radioactivity in the environment, the status of the communication system, the amount of debris in the streets, the fire hazard and the condition and numbers of personnel remaining after the attack.

Other areas may receive only early radioactive fallout which not only presents a hazard to inadequately sheltered personnel, but can result in contamination of exposed waters and structures. The radioactivity in the environment will present a serious problem in early reconnaissance and assessment.

Still other areas will receive only delayed fallout from a distant blast and be otherwise unaffected. Here, the immediate postattack operations of the water utility will be no different from normal operations. Later, when recovery is being initiated, personnel from these areas can render assistance and may supply water for survivors to other areas.

RECONNAISSANCE AND ASSESSMENT

In the early postattack assessment the status of communications is all important. The utility should provide for a prompt accurate flow of information upon which to base decisions following an attack. Advance planning should provide for the use of government reports, aerial monitoring and damage assessment, weather reports, information from civil defense control center, intercommunication with sheltered waterworks personnel, information from automatic controls and electronic sensing equipment, and information from waterworks and other civil defense personnel located where limited early assessment is possible.

As soon as the radiation intensity is low enough to permit leaving the shelter for short periods, probing operations should be planned to supplement the information obtained to date and to improve the assessment of damage. The information would be gained during a short period sufficient to permit decisions as to priority needs of personnel, equipment and material. The weaknesses found in the vulnerability study would be the first place to look for damage in this phase.

The reconnaissance and assessment will have to determine where water is needed, where work is needed on the utility system, the urgency of doing such work, the hazards involved in getting it accomplished, the time needed to do it, etc. As an important part of the assessment, procedures should be established for determining the postattack availability of waterworks personnel. This would involve communication and the use of personnel records. In the assessment operation, procedures are needed not only for evaluating the capability of the surviving system and for the use of applicable records, but for recording and disseminating assessment and evaluation information to the staff as needed. The assessment operation should provide for procedures for estimating the manpower, equipment and material needs to recover a sufficient system to provide at least 10 gallons of water per capita per day in the early postattack recovery period.

Assessing the Radioactivity of the Environment

Information on the radiological condition of the environment can be obtained from data received by means of radio communications, from fixed station radiological monitoring at the control centers and other shelters, or from monitoring by reconnaissance of field crews. The shelters may be equipped to take direct readings of the radiological level of the air directly outside.

Radiological evaluators should be trained by the water utility to advise utility command personnel. The duties of these radiological personnel would be to evaluate the available radiological information taken from all possible sources and then to plan to minimize the radiological hazard to surviving personnel; to determine when the shelters can be left, who can leave, and for how long a period of time; to determine the level of radiological risk; and to advise personnel on radiological hazards. The knowledge

of the radiological evaluators will be of special importance in the immediate postattack period. At this time they would assess the buildup of fallout and predict the fallout using UF wind data. They would then plan appropriate remedial measures for the protection of personnel and the utility system.

During the emergency phase when shelters can be left for only a very short period of time, if at all, the radiological evaluators will maintain communications with all available sources of radiological information. Data plots will be prepared showing radiation levels in the utility and neighboring areas. A continuing check will be maintained on personnel dosage records. Utility personnel will be appropriately advised if better shelters are available and can be reached without receiving excessive radiation. Where early fallout has occurred and personnel are required to leave shelters for reconnaissance or to perform essential work, they will be advised on using maximum protection against exposure or contact with radioactive materials. They will also be advised on the posting of facilities and areas which are contaminated with warning signs on all avenues of approach so that recovery personnel may avoid unnecessary exposure.

In the operational recovery phase, radiological evaluators will continue to monitor and assess the environment. Personnel will be leaving the shelters for longer periods of time and the remaining stay times of individuals must be determined so that no one person will receive an excessive amount of radiation. The radiological evaluators will have to advise on which facilities are affected by the radioactivity and which are not, on where it is safe to travel and where it is not safe. In critical areas where there is significant contamination, plans must be prepared to decontaminate and to cleanse. The radiological evaluators will oversee this operation. They will also advise on further remedial movement.

Assessing the Radioactivity of the Water Supply

The possible contamination by radioactivity of the water supply will be one of the primary concerns following a nuclear attack. The portable survey meters can be used both in disaster areas and laboratories to determine the levels of radiation from fallout in the water.

Indirect methods are also available for detecting and estimating the concentration of radioactivity in water subjected to early fallout. These methods are not as accurate as direct measurement but may be useful under early postattack circumstances. Two methods for relating the fallout radiation intensity of the surrounding land area to the concentration of radioactivity in waters of the reservoir are given below.

1. The radioactivity dispersed in the waters of an open reservoir may be estimated from the fallout radiation intensity on surrounding land areas by means of the following series of assumptions:

- a) The land area has a shielding factor due to surface irregularities of 0.7.
- b) The detection instrument reads 25 percent low because of its directional response and shielding by the operator.
- c) The gamma ray energy of the fallout is 0.6 million electron volts (Mev). For this energy the radiation intensity three feet above an ideal plane is 4.6 r/hr for a fallout density of one megacurie per square mile.
- d) The fallout is uniformly mixed throughout the body of water.

By appropriately combining the factors implied in the above assumption, the water radioactivity is given by the equation,

$$\text{Water Radioactivity in } \mu\text{c/l} = 500 \times \frac{\text{Radiation intensity (r/hr at 3 ft above surrounding area)}}{\text{Average depth of water (ft)}}$$

2. Assuming that fallout particles in the water have the same light scattering characteristics and the same specific gravity as the silica particles used in standard turbidity suspension, the fallout can be measured as an increase in turbidity. It has been observed that for each 0.015 gm/ft² of fallout deposition from a land surface detonation¹ the radiation intensity is one r/hr at H + 1. Then by using the assumptions of Method 1 above, the radiation intensity for each unit of turbidity represent about 1000 $\mu\text{c/l}$ gross radiation activity at (H + 1). The activity at later times would be determined from an assumed or measured decay rate.

Table VIII presents, for the specified assumptions, the estimated quantities of turbidity and corresponding radioactivity for various fallout radiation intensities at (H + 1) when there is uniform dispersion throughout various depths of water. Table VIII also provides a means, in the absence of more accurate radioactivity determination, of estimating radioactivity in water at various periods after the nuclear detonation. For example, if the radiation intensity above land surface at H + 1 is 3,000 r/hr at an average water depth of 20 feet and a turbidity unit of 7.5 after H + 24 the radioactivity will be 150 $\mu\text{c/l}$ at H + 24, 75 $\mu\text{c/l}$ at H + 48, 45 $\mu\text{c/l}$ at H + 72. Therefore, an estimate of the radioactivity concentration can be made by multiplying the turbidity measurement at 1 day by 20, at 2 days by 10 and at 3 days by 6.

1. For maximum intensities from 50 percent fission yield megaton range weapon.

TABLE VIII
ESTIMATED CONCENTRATION OF TURBIDITY AND RADIOACTIVITY IN STORED WATER
BASED ON FALLOUT RADIATION INTENSITIES OF SURROUNDING AREA

| Radiation Intensity above Land Surface at H+1 r/hr | Average Depth Of Water feet | Uniformly Dispersed No Decay | | Turbidity units | Radioactivity $\mu\text{C/l}$ | | With 90% Removal by Sedimentation Radioactive Decay Follows the t ^{-1.2} Curve* | |
|---|--------------------------------|---------------------------------|----------------------------------|--------------------|----------------------------------|--------------------|---|--------------------|
| | | Turbidity units | Radioactivity $\mu\text{C/l}$ | | After H + 24 | Turbidity units | 1 Day H + 24 | 30 Days H + 720 |
| 5,000 | 10 | 250 | 250,000 | 25 | 500 | 150 | 35 | 10 |
| | 20 | 125 | 125,000 | 12.5 | 250 | 75 | 18 | 5 |
| | 50 | 50 | 50,000 | 5 | 100 | 30 | 7 | 2 |
| 3,000 | 10 | 150 | 150,000 | 15 | 300 | 90 | 21 | 6 |
| | 20 | 75 | 75,000 | 7.5 | 150 | 45 | 10 | 3 |
| | 50 | 30 | 30,000 | 3 | 60 | 18 | 4 | 1 |
| 1,000 | 10 | 50 | 50,000 | 5 | 100 | 30 | 7 | 2 |
| | 20 | 25 | 25,000 | 2.5 | 50 | 15 | 4 | 1 |
| | 50 | 10 | 10,000 | 1 | 20 | 6 | 1 | 0.4 |
| 500 | 10 | 25 | 25,000 | 2.5 | 50 | 15 | 4 | 1 |
| | 20 | 12.5 | 12,500 | 1 | 25 | 8 | 2 | 0.5 |
| | 50 | 5 | 5,000 | 0.5 | 10 | 3 | 0.7 | 0.2 |
| 150 | 10 | 7.5 | 7,500 | 0.8 | 15 | 4 | 1 | 0.3 |
| | 20 | 4 | 4,000 | 0.4 | 8 | 2 | 0.5 | 0.2 |
| | 50 | 1.5 | 1,500 | 0.2 | 3 | 1 | 0.2 | 0.06 |
| 15 | 10 | 0.8 | 750 | 0.08 | 1.5 | 0.8 | 0.4 | 0.03 |
| | 20 | 0.4 | 400 | 0.04 | 0.8 | 0.4 | 0.2 | 0.015 |
| | 50 | 0.2 | 150 | 0.02 | 0.3 | 0.2 | 0.09 | 0.006 |

*Assumption: (1) Fallout of 0.015 grams/ft²/r/hr at (H + 1)
 (2) That 90% of the Fallout will settle within 24 hours
 (3) That the remaining 10% is uniformly dispersed
 (4) That decay follows that t^{-1.2} curve and is the only factor acting to reduce the radioactivity concentration

The Internal Radiation Hazard

The internal radiation hazard has been evaluated and the result reported by the National Academy of Science - National Research Council as well as the Department of Defense - Office of Civil Defense. In general, radiation from sublethal concentrations of internally deposited radionuclides act slowly, and its results do not become apparent for years. Therefore, the internal radiation hazard is not among the forces which will weaken the population and reduce its immediate ability to cope with a radically altered environment.

Assessing the Physical Damage

The extent of physical damage to the water utility structures and equipment will also have to be investigated and assessed. The reconnaissance will cover the intake facilities, treatment works, transmission lines, source facilities, distribution piping, pumping stations and storage facilities. The condition of these facilities and their operational capability will have to be determined. The integrity of the distribution system, its ability to retain the water supply and to maintain pressure, and the level of pressure, will be an important part of the assessment. The extent of damage to the power facilities will also have to be investigated. Along with the damage assessment, determinations would have to be made as to the type and amount of repairs necessary to put the system back into operating condition, the amount of equipment and personnel needed to do this and the time necessary to accomplish the work.

EFFECTS OF FALLOUT ON RESTORATION

Exposure Limits for Personnel

Before beginning recovery and repair actions at a waterworks facility, an assessment of the character and extent of the radioactive fallout contamination must be made so that necessary precautions may be taken for the protection of the waterworks personnel.

To minimize exposure to radiation, the movement of personnel from shelters to perform essential work must be controlled. Radiation intensity, total exposure dose, accumulated dose, and dose rate must be thoroughly understood and respected by every waterworks employee. Control of entry time, time of stay, shielding and distance of separation from fallout material is required.

The most urgent repairs should be made (after necessary minimal decontamination) and the less urgently needed repairs should be deferred for a sufficient time for the radioactive decay to reduce the hazard in the area. If the job would result in overexposure when assigned to one individual, the additional workmen should be assigned in such a manner that none of them are overexposed and lost to later recovery operations.

The risk in permitting any given individual to leave the shelter can be determined knowing the existing accumulated radiation dose, the expected radiation dose outside the shelter, and the radiation doses which will result in varying expected degrees of injury. The radiation exposure dose which workmen outside shelters will receive at given times after an explosion may be estimated using the curves or nomograms presented in Figures 12 and 13 or 14 and 15 in Chapter III. The predicted relationship between the radiation dose and injury is given in Table I in Chapter II.

Water Needs of Community

As part of the reconnaissance and assessment the water utility in conjunction with other civil defense agencies must locate the survivors and obtain some idea of their numbers and distribution so as to estimate their water needs. The need for water must be determined not only for the sustenance of life, but for fire suppression, sanitation, decontamination and the basic necessary industrial and commercial processes. Along with these water needs it must be determined whether a water supply of sufficient quality and quantity is available for these consumers from the utility system or whether outside sources of supply or portable treatment facilities are needed. If the utility water supply is not adequate, then reconnaissance combined with information obtained from radio communications and from advance planning inventories should assist in locating satisfactory auxiliary supplies and/or portable treatment works.

Urgency and Priority of Action

As water is critically essential for human survival, there will be an urgent need for it following a nuclear attack. The decision to act to restore a water facility should be based on the needs for the restoration of the particular facility and the numbers of persons who would benefit. This is the concept of the "greatest good for the greatest number." Water utility workers should not be exposed to significant radiation levels unless such action is essential for the welfare and rehabilitation of the community or of the workers themselves. Limited exposure is justifiable for securing essential supplies, decontaminating needed facilities, repairing needed damaged structures, etc. The possible effects of the exposure must be balanced against the benefit that would be gained.

REFERENCES

- (1) "Permissible Emergency Levels of Radioactivity in Water and Food,"
TD-11-8, Office of Civil Defense, Washington D.C. (March 1962).
- (2) "Personal and Family Survival" Office of Civil Defense. SM 3-11
(Revised) May 1963, Washington D.C.

CHAPTER VI

RECOVERY OF PLANT OPERATION

INTRODUCTION

The objective of this chapter is to present methods and procedures to be used during a postattack recovery period for emergency repair, restoration and operation of a domestic water supply system that has experienced the effects of nuclear warfare. Consideration is given to the activation of procedures that were formulated as part of the utility's advance planning program and incorporated in the disaster plan developed by the utility to minimize the effects of a nuclear attack and to facilitate recovery.

RECOVERY ORGANIZATION AND LIAISON

Organization

One of the first steps to be taken by the water utility following an attack is the activation of the utility's Civil Defense disaster organization. The effectiveness of the recovery operation will be reflected to a large extent by the adequacy of this organization that has been formed during the pre-attack period after preparation of the utility disaster plan. The disaster plan itself is developed by a disaster coordinator. In the larger utilities the disaster office is provided with a staff of full-time employees. This office will normally make use of an advisory committee of personnel from the various departments of the utility.

The utility disaster organization, which will operate during recovery, will consist of both regular and auxiliary emergency waterworks personnel. Channels of command must be established within the organization. The chain of command and succession should be established for all command posts, control points, and assembly areas. For the key positions, alternates with replacements at least three deep should be designated. Recovery can be expedited in some systems by dividing the system into self-sufficient zones for disaster operation. There must be a clear designation of authority and responsibility within the organization.

Liaison and Mutual Aid

For joint prosecution and recovery, cooperative and coordinated post-attack operations are needed. Liaison with other Civil Defense units will be made shortly after the attack. Mutual aid agreements incorporated in advance planning should call for exchange or assignment of personnel, machinery and stocks of essential materials and equipment during emergencies. These agreements are made with Civil Defense authorities (community, county or other

local area, State and Federal organizations, and the military); other utilities (water, electric, telephone and gas); public service groups (health, public works, fire, welfare, transportation, police, communications, and public information); and other interested agencies. The mutual aid agreements should call for a definition of and an assignment of responsibilities. Of special importance are agreements for the use of emergency water from interconnections with adjacent water utilities and adjacent industrial or other private auxiliary supplies.

Records

Recovery personnel will need clear and informative records to adequately pursue their responsibilities. The availability of such records at convenient, protected locations will expedite the recovery operations. The use of duplicate records will result in a greater likelihood of their being available. The records should cover all essential data including disaster operation procedures and organization. The essential records on the water system would include up-to-date maps, engineering plans, operating procedures, personnel records, stock inventories, consumer accounts and legal documents. Of special importance are information on potential emergency sources, emergency stock-piled equipment and materials, and the location and maintenance records on valves and gates. Records pertaining to mutual aid will be needed. Personnel records should be kept for every one on emergency utility and auxiliary service. Records of radiation exposure are of special importance and should be maintained throughout the recovery period. All records should be kept up-to-date.

OPERATIONAL CENTERS

Control Locations

Control locations are established within the utility for the purpose of organizing the utility postattack recovery operation. The top utility management and defense personnel will be located at the command post shelter and will provide the over-all direction of the recovery operation. Other control points will receive direction from the utility command post and they in turn will give direction to the various assembly areas. These centers will, of course, be shelter areas. In the smaller utilities the command post, control and assembly centers may all be at one location. Pertinent information will be received from all available sources and radio communication will normally be used between the centers. Several or more control points may be designated if it would be advantageous for the disaster operation of the particular utility. If the water system is divided into self-sufficient zones, each zone may be under the direction of one of the control point headquarters.

Assembly Areas

Every assembly area will report to and will receive instructions and directions from control points regarding their specific postattack recovery

function. Personnel in assembly areas will be responsible for local post-attack recovery functions. Both mobile and field task forces are organized to carry out these functions as soon as radiological conditions permit. The field task forces will normally be restricted to working in a particular area. The mobile task forces will be operating at much greater distances from their headquarters and may not be confined to use in one assembly area or one control location area.

The recovery task forces may be the same as those responsible for reconnaissance and assessment. The task forces will control water loss and conserve quality water; isolate damaged portions of the distribution system and contaminated facilities; activate emergency sources; treat water storage and distribution facilities; reactivate easily recoverable system facilities having high priority needs; and do improvised operation and repair work. The task forces will also initiate procedures that have been prepared for supplying survival water to consumers from the community system, by hauling in water, or by evacuating the survivors to areas having water. The notification of location and quality of emergency water would be made public through radios, loudspeakers, posters or other methods.

WATER UTILITY STRUCTURES

Fire Control

Water utility structures are generally not built of highly flammable materials and it is unlikely that very extensive fire damage will be caused by thermal radiation. However, some ignition points will probably be present and care should be taken to extinguish small fires in the vicinity of the waterworks facilities that may result in serious fire damage. In places where fires may start, water connections and hoses should be made available close by. In some areas the use of automatic fire sprinklers might be considered. Fire control will have high priority and will normally be done in close cooperation with other agencies.

Debris Removal

Radiological monitoring in the vicinity of the debris will be a necessity. Large quantities of debris lying in the streets will make postattack recovery operations extremely difficult by preventing or slowing down travel to critical locations. Debris may also result in radiological or other contamination of raw or treated waters and recovery personnel should investigate this possibility. Clearance of debris can be accomplished by the use of hand shovels, wheelbarrows, hand push brooms, drag-type scrapers and skip loaders. Debris may be moved to a safer more isolated area or may be buried.

RADIOLOGICAL DECONTAMINATION

The high priority facilities and critical areas which are found to contain significant radiological contamination must be decontaminated. When the decision is made to recover a contaminated installation or area, a site is

chosen from which to start the recovery operation. The contaminated facility is monitored and its physical condition inspected. The effectiveness of decontamination measures may be tested. To prepare effectively for decontamination it may be necessary to remove debris and obstructions and to check the adequacy of the water supply available for decontamination and of drainage channels that may have to be used. Boundaries of critical radioactive areas should be marked and posted. This may have already been done by reconnaissance personnel.

Personnel Protection

Radiological decontamination should be accomplished under the supervision of trained personnel. Decontamination workers should wear dosimeters and keep close track of the total amount of radiation they are receiving. The use of these measuring instruments and precautions necessary in radioactive areas have been discussed in previous chapters of this manual. The use of protective clothing is of minor importance.

Decontamination Methods

Decontamination of facilities may be accomplished by the removing or decreasing the sand like fallout material; by covering with uncontaminated soil or other material; or by natural decay. Removing or decreasing the contamination can be done by two general methods - wet and dry. In the wet method water is used and must be available in ample quantities. The dry method is conducted without water. If water is used for decontamination purposes it will become slightly contaminated itself. The safety of its disposal therefore, does not have to be considered too much.

Surface decontamination methods, classified by type of surface, are listed in Table IX. The advantages and disadvantages of each method for various surfaces is indicated.

Paved area decontamination can be done by wet methods using water hoses and street flushers or by dry methods using motorized "street" sweepers, vacuumized "street" sweepers, air brooms, vacuum cleaners and hand push brooms. Unpaved area decontamination can be accomplished using motorized scrapers, motor graders, bulldozers, plows, hand shovels and wheelbarrows. Both paved and unpaved areas can be covered with uncontaminated fill. Structures can be decontaminated by such methods as water hosing, using a roof washdown system, and scrubbing with water plus wetting agent, or by dry methods such as vacuum cleaning, hand push brooms, canvas covers, using solvents or strippable coatings and sandblasting. Equipment decontamination can be done by wet methods using water hoses, scrubbing with water plus wetting agent, and steam cleaning, or by dry methods using vacuum cleaning, covers, solvents, and air jets.

Personnel decontamination is usually not necessary after the operation is finished. Laundering is effective in reducing the radioactivity of clothing and fabrics to very low levels.

TABLE IX
SURFACE DECONTAMINATION METHODS
CLASSIFIED BY TYPE OF SURFACE*

| <u>Surface</u> | <u>Method</u> | <u>Advantages</u> | <u>Disadvantages</u> |
|----------------|---|---|---|
| Paint | Water | Most practical method for gross decontamination from a distance. Contamination reduced by approximately 50 percent. | Protection needed from contaminated spray. Runoff must be controlled. Water under high pressure should not be used on a surface covered with contaminated dust. |
| | Steam (with detergent if available) | Most practical method for decontaminating large horizontal, vertical, and overhead surfaces. Contamination reduced by approximately 90 percent. | Same as for water. |
| | Soapless detergents | Where effective, reduces activity to safe level in 1 or 2 applications. | Mild action. |
| | Complexing agents: Oxalates, carbonates, citrates | Hold contamination in solution. Contamination on unweathered surfaces reduced by approximately 75 percent in 4 minutes. Easily stored, nontoxic, non-corrosive. | Requires application from 5 to 30 minutes for effectiveness. Has little penetrating power; hence, of small value on weathered surfaces. |
| | Organic solvents | Quick dissolving action makes solvents useful on vertical and overhead surface. | Toxic and flammable. Requires good ventilation and fire precautions. |
| | Caustics | Minimum contact with contaminated surface. Contamination reduced almost 100 percent. | Applicable only on horizontal surfaces. Personnel hazard. Not to be used on aluminum or magnesium. |

TABLE IX (Continued)

| <u>Surface</u> | <u>Method</u> | <u>Advantages</u> | <u>Disadvantages</u> |
|----------------|--|---|---|
| Metal | Abrasion (wet sandblasting) | Complete removal of surface and contamination. Feasible for large-scale operations. | Contaminated sand spread over large area. Method too harsh for many surfaces. |
| | Water | Contamination reduced by approximately 50 percent. | Same as for painted surfaces. |
| | Detergents | Removal of oil or grease films. | Do. |
| | Organic solvents | Stripping of grease. | Do. |
| | Complexing agents: Oxalates, carbonates, citrates. | Holds contamination in solution. | Difficult to keep in place on any but horizontal surfaces. Limited value on weathered or porous surfaces. |
| | Inorganic acids | Fast, complete decontamination. | Good ventilation required; acid fumes toxic to personnel. Possibility of excessive corrosion. Acid mixture cannot be safely heated. |
| | Acid mixtures | Action of weak acid. Reduces contamination of unweathered surfaces. | Same as for inorganic acids. |
| | Abrasion (buffers, grinders) | Useful for detailed cleaning. | Follow-up procedure required to pick up powdered contamination. |
| | Abrasion (wet sandblasting) | Same as for painted surfaces. | Same as for painted surfaces. |

TABLE IX (Continued)

| <u>Surface</u> | <u>Method</u> | <u>Advantages</u> | <u>Disadvantages</u> |
|----------------|----------------------------|---|---|
| Concrete | Abrasion (vacuum blasting) | Direct removal of contaminated dust. | Contamination of equipment. |
| | Vacuum cleaning | Same as for vacuum blasting on concrete. | Same as for vacuum blasting on concrete. |
| | Flame cleaning | Only method of trapping contamination on surface. | Slow and painstaking. Fire and airborne radiation hazard is great. |
| Brick | Same as for concrete. | Same as for concrete. | Same as for concrete. |
| Asphalt | Abrasion | No direct contact with surface; contamination may be reduced to safe level. | Residual contamination fixed into asphalt. If road is subject to further contamination, may require recovering. |
| | Flame cleaning | Same as for flame cleaning on concrete. | Same as for flame cleaning on concrete. |
| Wood | Flame cleaning | Same as for flame cleaning on concrete. | Same as for flame cleaning on concrete. |

* Data from Industrial Defense, The Provost Marshal General's School, U. S. Army based on research, sponsored by the Office of Civil Defense.

REPAIR

Initiation of Repairs

A decision can be made as to when to begin certain repairs or operational actions by making use of the following information obtained from reconnaissance and assessment during the early postattack recovery period:

- 1) The relative importance of the facility or area, the urgency in returning it to use and the consequences if restoration is postponed for a period to permit additional decay.
- 2) The existing radiation intensity of the facility or area.
- 3) Length of time required to perform function (as shown in Table X).
- 4) The travel time and work time which govern the amount of radiation outside the shelter that personnel will receive.
- 5) The number, availability, and condition of trained personnel and equipment to do the specific job.
- 6) The existing accumulated radiation dose of the personnel.
- 7) The feasible decontamination procedures.

During the period that radioactivity is at a critical level, urgent repairs for reactivation of easily recoverable system facilities having high priority can be made after necessary minimal decontamination. The less urgently needed repairs can be done after sufficient time has taken place for the radioactive decay to reduce the hazard in the area.

Repair Personnel

Repair personnel should be thoroughly trained in emergency repair procedures. They should be provided with the necessary equipment and repair items to properly repair any reasonable amount of damage done to raw water, pumping, treatment, storage and distribution system facilities. As previously mentioned, adequate records should be kept of their radiological exposure.

Repair Requirements

The time required for repair during early recovery will depend on the workmen, equipment and materials that are available postattack, the level of radioactive fallout and the extent and character of the damage. Table X shows the time, manpower and equipment requirements for typical emergency operations. For descriptive purposes an operational guide is presented in Table XI. This guide shows required manpower for recovery and restoration assuming light, moderate and severe damage and has been time-phased in accordance with an assumed recovery for a system supplying one million people. The

TABLE - X - TIME REQUIREMENTS FOR EMERGENCY OPERATION OF WATERWORKS FACILITIES

| Type Facility | Operation | No. of Men (Typical) | Time Required - Minutes | | | | Equipment | | |
|---------------------------------|---|-------------------------|-------------------------|----------|------------------------|----------|-----------|----------|--|
| | | | Manual Conditions* | | Emergency Conditions** | | | | |
| | | | Min. | Ave. | Min. | Ave. | | | |
| Deep well plant (electric) | Startup (each unit) | 1 | 1 | 15 | 5 | 60 | 180 | 120 | Emergency Lights, Tools |
| | Shutdown - " | 1 | 1 | 3 | 1 | 60 | 180 | 120 | Emergency Lights, Tools |
| | Maintenance & Inspection (each unit) | 1 | 1 | 5 | 3 | 60 | 300 | 120 | Emergency Lights, Tools |
| Booster plant (electric) | Startup (each unit) | 1 | 1 | 5 | 3 | 60 | 180 | 120 | Emergency Lights, Tools |
| | Shutdown - " | 1 | 1 | 1 | 1 | 60 | 180 | 120 | Emergency Lights, Tools |
| | Maintenance & Inspection (each unit) | 1 | 1 | 5 | 3 | 60 | 180 | 120 | Emergency Lights, Tools |
| Booster Pumping Plant | Hookup portable generator or portable gasoline-powered pump unit (connections available). | 3 | 60 | 240 | 120 | 240 | 480 | 360 | Emergency Lights, Tools |
| Reservoir Outlet | Isolation of reservoir | 2 | 10 | 60 | 30 | 120 | 240 | 180 | Emergency Lights, Tools |
| Regular Cl ₂ Station | Startup (each unit) | 1 | 5 | 15 | 10 | 60 | 180 | 120 | Gas Mask, Emergency Lights, Tools |
| Standby Cl ₂ Station | Startup (each unit) | 2 | 15 | 120 | 60 | 120 | 240 | 180 | Gas Mask, Emergency Lights, Tools |
| | Shutdown - " | 1 | 1 | 5 | 2 | 60 | 120 | 90 | Gas Mask, Emergency Lights, Tools |
| | Maintenance & Inspection (each unit) | 1 | 1 | 3 | 2 | 60 | 120 | 90 | Gas Mask, Emergency Lights, Tools |
| | Cl ₂ Cyl chge 1 ton | 2 | 10 | 60 | 20 | 120 | 240 | 180 | Gas Mask, Emergency Lights, Tools |
| | Cl ₂ Cyl chge 1500 | 1 | 5 | 15 | 10 | 120 | 180 | 150 | Gas Mask, Emergency Lights, Tools |
| Distribution System | Open/close valves less than 24", manual oper. | 2 | 1 | 10 | 5 | 60 | 180 | 120 | Gate key - Lights |
| | Open/close valves 24" and over, power oper. | 2 | 5 | 30 | 20 | 60 | 240 | 180 | Gate truck with compr. air motor, or elec. motor - Lights |
| | Regulator-activate standby units (each unit) | 2 | 15 | 45 | 30 | 60 | 240 | 120 | Gate key, gages - Lights |
| | Close or shut 3" to 12" serv. conn. | 2 | 1 | 10 | 5 | 60 | 180 | 120 | Gate key - Lights |
| | Repair leak 12" main, (using repair clamp or above, incl. shutdown time) | 6 | 20 (hrs) | 20 (hrs) | 5 (hrs) | 30 (hrs) | 30 (hrs) | 10 (hrs) | Repair truck, Compressor & Tools, Excavation equipment - Lights |
| | Repair major leak (24" pipe or less) | 10 | 3 | 25 | 10 | 4 | 30 | 15 | As above. |
| | Disinfect 4" to 24" main, (per 1000') | 3 | 4 | 8 | 6 | 4 | 16 | 12 | Mobile Cl ₂ unit, test equipment, Gate truck equipment - Lights |

* Time requirements for typical operations. (Based on experienced operators performing essential operations. Travel time not included.)

** Time requirements under emergency conditions (flooded, debris, panic, limited communications).

TABLE XI

OPERATIONAL GUIDE

EARLY POSTATTACK RECOVERY AND EMERGENCY RESTORATION OF WATER SUPPLY SYSTEMS
EXPERIENCING LIGHT, MODERATE AND SEVERE DAMAGE

| | Time Phase (for starting) | Manpower* (Man days) Extent of Damage | | |
|--|------------------------------|--|---------------|----------------|
| | | Light | Moderate | Severe |
| Initial appraisal of attack and effect on water system | D day +1 | 1-5 40-80 | 1-5 60-100 | 1-5 100-150 |
| Initial assessment of damage to facilities | +2 | 50-100 | 75-200 | 100-300 |
| Develop preliminary operations plan (revised as assessment information improves) Conserve quality water in storage (continuation of program of alert period) | +4 | 75-200 | 100-300 | 150-500 |
| Detailed assessment of damage and evaluation of system Activate standby sources, including poor-quality water for fire control and decontamination. Control water loss through damaged distribution system, reservoirs, and transmission lines. | +7 | 1,000-2,000 | 1,500-3,000 | 2,500-4,000 |
| Initiate recovery of sources, treatment, and transmission facilities. Reactivate use of stored quality water. Initiate quality water service to critical and high-priority users. Complete detailed plans for restoration of facilities Continue recovery operations to supply 10 to 40 gallons per day per survivor through distribution system | +14 (to 1 yr) | 8,500-17,000 | 15,000-40,000 | 25,000-50,000 |

*Estimated manpower for recovery and emergency restoration of water supply system serving 1 million persons.
Personnel for operation of system not included.

guide also assumes that fallout makes decontamination operations necessary along with the need for controlling entry time and stay time in work areas up to seven days after the nuclear burst. Additional guides listing the number of man-hours to repair water mains of various materials and sizes are given in Tables XII and XIII.

Water Treatment Facilities

Repair crews will be responsible during the recovery period for getting the permanent water treatment facilities back into operation and for installing temporary mobile treatment facilities if they are needed. During the disaster it may be necessary to use any water that is available for survival. It may not be possible to meet the commonly used drinking water quality standards under all disaster conditions. The primary quality considerations for potable water under such circumstances will not be radioactivity, but will be sewage contamination and contamination with other highly toxic material.

The treatment facilities may be continued in use even though they do not provide a potable supply if their use will lower the hazard resulting from the various uses the supply may be put to. If the supply in the system is not considered potable, and potable treatment facilities are not available which can effectively treat the water, then an acceptable supply will have to be brought in for the survivors.

Power

Repair crews may find that the normal electric power sources for operation of the water system have been inactivated. It is in emergency situations such as this that the provision of standby self-contained power units at critical locations is found to be invaluable. If such facilities have not been installed, or are not in operating condition, portable units will have to be brought in. These units may belong to the water utility or to a power company, military or civil defense organization. The utility records should adequately cover the power needs for each critical facility and show where and how adequate auxiliary sources of power and fuel can be obtained. The utility itself should have portable fuel powered units, portable generators and an adequate supply of fuel stockpiled at convenient, protected locations. Priorities should be established for use of available power within the utility.

TABLE XII

MAN-HOURS TO REPAIR WATER MAINS OF VARIOUS MATERIALS

| Material | 4-inch | 6-inch | 8-inch | 12-inch | 16-inch | 18-inch | 20-inch | 24-inch | 30-inch | 36-inch |
|--------------------------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|
| Steel | 8 | 10 | 16 | 11 | 13 | - | 9 | 25 | 12.5 | 33 |
| Cast Iron | 12 | 21 | 33 | 13 | 131 | 10.5 | 18 | 30 | 107 | 107 |
| Asbestos-Cement | 24 | 49 | 30 | 112 | - | - | - | - | - | - |
| Weighted Ave. for all | 11 | 19 | 26 | 30 | 31 | - | 13.6 | 30 | 28 | 72 |

TABLE XIII

MAN-HOURS FOR REPAIR OF VARIOUS SIZE WATER MAINS

| Size | No. of Repairs | Total Man-Hours | Ave. Time/Repair |
|----------------|----------------|-----------------|------------------|
| 4 in to 8 in | 87 | 1,679 | 19 man-hours |
| 12 in to 18 in | 49 | 1,029 | 21 |
| 20 in to 30 in | 54 | 1,278 | 24 |
| 36 in | 11 | 432 | 39 |
| All Sizes | 201 | 4,418 | 22 |

REFERENCES

- (1) "Industrial Defense", The Provost Marshal General's School, U.S. Army, Fort Gordon, Georgia (June 1962).

CHAPTER VII

EMERGENCY SOURCES AND SUPPLY PROCEDURES

INTRODUCTION

The locating, inventorying and planning for the use of emergency water sources from which minimum supplies can be delivered to survivors of a nuclear disaster is one of the most important advance preparation considerations. The Office of Civil Defense has indicated that shelter supplies should include stored water sufficient for at least 14 days. When the water supplies stored in shelters are exhausted, people will expect Civil Defense and the water utility to have a supply available. Water will have to be available to survivors at locations which can be reached without exposure to excessive residual radioactivity.

It is possible that all or part of the normal water supply system will be destroyed beyond repair. In areas where the utility water supply is not usable or the water distribution system is inoperative, the success with which essential water is supplied from alternate facilities will influence greatly the over-all impact of the attack. The emergency provision of essential water by the water utility and/or other agencies having mutual aid responsibilities should therefore be thoroughly planned in advance. Emergency supply procedures include the use of water allowances or rationing and the means of delivery of both potable and non-potable water. Delivery of emergency water may not necessarily be the direct or sole responsibility of the utility.

Each utility must make its plans in view of its own particular system and the facilities and sources available to it. Decisions must be made recognizing the seriousness of the results of an attack and also recognizing that the measures decided upon must be both reasonable and practicable.

EMERGENCY SOURCES

Postattack water may be available either from local or imported sources. These may be sources in use at the time of the attack, from water in storage, or from auxiliary or alternate sources of supply. In addition, emergency sources in the household itself should not be overlooked and the survivors should be notified of the possibility of such sources being available.

The procedures and the time required for the recovery of a particular source of water by the utility is dependent on the character of the facility and its pre-attack condition. Underground sources would be much less likely to become contaminated than surface sources. If underground sources are not available or expedient to use the only recourse is to use surface supplies.

In rivers and lakes, inlet structures may be so constructed that little or no special hardening is necessary; however intakes which are an integral part of the dam or reservoir wall will require careful consideration.

Local Sources

The best source of emergency water is the utility system itself if it is operative in or near the area of need. The next logical source is from auxiliary supplies within or adjacent to the distribution area. Sources that are not normally considered potable may have to be used, and treatment may be needed.

Interconnections with adjacent water utilities with water capable of being delivered in either direction are highly desirable. The reduced sizes of mains at the edges of the utility system will decrease the amount of water available through such interconnections and pumping may be necessary.

Local industrial, irrigation or other private supplies can similarly be used for supplying emergency water. Water storage on private properties including tanks, reservoirs, and swimming pools may be another possible source of supply. Consideration should also be given to the appreciable volume of water stored in building water tanks, water heaters, and building water piping, water softeners and cooling towers. The total volume, however, may be only a very small part of that required. Local surface waters not normally used for domestic purposes, such as lakes, ponds, rivers, streams and canals offer tremendous volumes of water for fire fighting, decontamination, and sanitary purposes. Salt water sources, if available, from the ocean, bays and estuaries, out of necessity may also have to be used for such purposes if fresh water sources are not available in sufficient quantities. In using these sources consideration must be given to their accessibility for emergency pumping, their location in relation to the supplying of points of need, and their possible treatment requirements.

Some municipalities now require the owners of pools and other large storage facilities to provide a pipe connection by which the fire department may use the water as a source of emergency supply.

Underground cisterns as used in San Francisco since the disastrous fire and earthquake in 1906 are an excellent source of emergency water and might be considered in the emergency planning of other municipalities. In San Francisco there are 152 fire department cisterns strategically located throughout the city. They are designed and maintained for use as an emergency water supply in the event of a major interruption of the normal supply. They are not connected with the water supply but are filled from fire hydrants by the fire department.

Imported Sources

If local sources of supply are not available for emergency use, then imported sources must be considered. Imported sources may be those already

used by the utility such as the taking of water from aqueducts constructed to bring a supply to the community from distant sources. Repairs may have to be made to continue the service of the water to the utility system. Once the water has reached the system the same considerations apply as to any of the local sources. Emergency pipelines can be laid to bring water in from sources that are not too far distant. Water may be delivered to normally dry stream beds or ditches or to storm sewers in order to carry it to the area of the utility and be available for use where needed.

It may be necessary to haul in water if the piping system is not usable. Hauled water could be the only source available to sustain survivors until more permanent delivery facilities are established. The amount of water available by hauling, as mentioned earlier, will probably be insignificant compared to the demand. Another problem will be the availability of sufficient fuel for large scale hauling.

Tank trucks used for hauling water can be commercial water-hauling trucks, milk trucks, street-flushing trucks, construction trucks, fire department trucks, or tank trucks owned by farmers. Small portable tanks may be mounted on trucks and used to deliver water. Procedures for delivering water by tank truck are discussed under "Supply Procedures" in this chapter.

Railroad tank cars are another means of hauling water. Normally water from railroad tank cars would have to be transferred to other vehicles for further hauling.

Another source of water which may be either local or imported is bottled water. It may be obtained from bottled water distributors or by using the bottling or canning facilities of dairies, breweries, soft drink companies, canneries, etc.

Household Sources

During the period that no water can be brought into a damaged area, or if the water present is of questionable quality, there are a number of emergency sources within the household. Water in the hot water tank and in the storage tanks of flush toilets could be used, as could the melted ice cubes in the refrigerator. Water packed fruit or vegetables and juices protected in cans are a good source of liquids. The consumers should be given specific instructions on safe drinking water and methods of purifying drinking water. A number of OCD pamphlets available give an excellent discussion of this.*

SUPPLY PROCEDURES

After the emergency water sources have been located and inventoried, the utility must consider the procedures by which the sources will be used to

* Emergency Sanitation at Home, OCD, August 1958,
Home Protection Exercises, A Family Action Program (MP-1), OCD, July 1960.

supply water to survivors under conditions that are likely to exist at the time of need. The efforts of utility personnel after leaving their shelters will be devoted primarily to recovering the system and bringing it back to a satisfactory operating condition as quickly as possible. During this time delivery of emergency water by improvised means may involve other agencies as well as the utility. The responsibility for delivering emergency water should be determined in advance.

Emergency Water Allowances

Water allowances, rationing, priorities, and time-phasing of estimated water requirements are an important consideration in advance planning. It will be necessary to inventory critical water users and determine their quantity and quality requirements. Following an attack water is likely to be available only in limited quantities and should be used on a priority basis, considering the over-all recovery needs. Different uses will have varying quantity and quality requirements. Such requirements will not remain constant but will change under the changing conditions following the disaster. The water utility will have to consider such changing conditions in the determination of use priority.

The determination of emergency water needs is made on the basis of both quantity and quality for various categories of use. The uses generally considered include potable, sanitary, decontamination, fire fighting, industrial, and agricultural water.

Potable water is that water which can be used for drinking and cooking. After a nuclear disaster the primary concern for potable water will be contamination by sewage, or other highly toxic material. Contaminated water which has been treated with chlorine or other disinfectant may have to be used without further treatment to assure its purity. The health department should be consulted whenever possible in determining the acceptability of the available supplies. The highest priority on available potable water supplies should be given to hospitals and other medical care facilities and to personnel engaged in recovery operations.

Sanitary water is used for personal washing, cleansing of living and work areas, and for flushing water carriage sewage facilities, provided there is sufficient water and facilities are useable. Sanitary water will be needed from the start of the disaster period, and especially when survivors start leaving their shelters. Although it is desirable that these waters meet potable standards when delivered through the potable water system, this may be impossible during the emergency.

The Office of Civil Defense has compiled information showing the minimum amount of potable and sanitary water that should be provided by the water utility during a disaster. These quantities are summarized in Table XIV.

Decontamination water is used for cleansing facilities, areas, buildings, persons, etc. Following a nuclear disaster one of its most important uses

is that of washing away radioactive fallout. Disposal of the used decontamination water may be a problem and should be reviewed with those having the responsibility for waste water disposal. The disposal to storm sewers, holding in storage lakes and/or land percolation are some methods that may be considered.

TABLE XIV

MINIMUM POTABLE AND SANITARY WATER QUANTITY REQUIREMENTS

| | |
|---|---------------------------|
| <u>Hospitals and other Medical care Facilities</u> | 5-25 gallons/casualty/day |
| <u>Mass-care Centers and other Welfare Installations</u> | |
| Lodging and emergency feeding | 5-15 gallons/person/day |
| Lodging centers - drinking, hand and face washing only. | 2 gallons/person/day |
| Lodging centers with operative flush-toilet facilities - drinking, feeding and sanitary uses. | 25 gallons/person/day |
| Mass-feeding stations - cooking and sanitary uses. | 3-10 gallons/person/day |
| <u>Households</u> | |
| Drinking, cooking and cleansing | 5-15 gallons/person/day |
| With operative flush-toilet facilities | 25 gallons/person/day |

Fire-fighting water is that water needed to control fires and cool debris. Large volumes of water are needed at fire areas and any water available may have to be used as long as it does not clog piping and pumping equipment.

Industrial water need after a disaster is that required to re-establish industries essential for survival or defense. The quantity and quality needs vary with the particular industry.

Agricultural water is used to irrigate crops. The required quantity and to a much lesser extent the quality of such water will depend on the specific type of crops being irrigated.

In planning the supplying of emergency water, water allowance scales can be prepared by estimating water requirements for specific water uses such as those reviewed above.

The disaster periods chosen for purposes of determining water allowance scales can be designated as survival, early recovery, restoration, and reconstruction. Survival allowances are the minimum amounts necessary to sustain human life. Early recovery operation allowances provide for the high-priority needs during the early disaster recovery period. The minimum quantities needed at this time will usually be provided under severe conditions for relatively short periods of time. Restoration operations will extend over a longer period of time and conditions will generally be less severe. During this period water allowances for some uses will begin to approach pre-emergency levels. Reconstruction operations will start when attention may be given to rehabilitation of the system and will extend over an appreciable period after the service of essential water has been started.

Appropriate allowances can be established corresponding to criteria associated with each of the above emergency conditions. Table XV shows estimated water allowances for given potable uses for each emergency period.

The estimated water requirements can be time-phased. Time studies of such requirements can be used to determine the minimum supplies, equipment, manpower and organization arrangements needed to meet the water requirements by designated postattack dates. As time passes following a disaster, increasing quantities of water must be made available to satisfy minimum water needs. The earliest water requirements will be mainly for drinking and for the care of the sick and disabled. Later when further radioactive decay permits greater recovery activity, increased quantities of water will be needed for decontamination and for the recovery of food processing and other essential industries. The time-phasing can be developed assuming time intervals for establishment of water allowance scales. One method of relating the time-phasing of minimum water allowances to predetermined water allowance scales as given in the previous table is shown in Table XVI. The date of the attack is referred to here as "D" day.

Delivery of Potable Water

In planning the distribution of emergency water, consideration can be given to the use of undamaged portions of the distribution system by rerouting and isolation, the use of normal or emergency sources of supply, the use of emergency mobile treatment equipment, and delivery of water to the system by hauling. The public will need information concerning the availability, location and condition of emergency water supplies throughout the survival and recovery phases.

The utility distribution system as mentioned earlier would be the best source of emergency water if it is operative and can be used. The destruction of key parts of the distribution system may prevent any sort of normal operation, but certain portions of the system may be capable of serving water to some of the consumers directly. Where the supply is limited the service might be intermittent and restricted to a few hours per day.

TABLE XV
ESTIMATED EMERGENCY WATER ALLOWANCE

| Water use Category and type of Facility or Operation | Water Allowance Unit | Estimated Water Allowance | | | |
|---|----------------------------|---------------------------|------------------------------|-----------------------------|--------------------------------|
| | | Scale A Survival | Scale B Early Recovery | Scale C Restora- tion | Scale D Recon- struction |
| <hr/> | | | | | |
| 1. Potable Water | | | | | |
| a. Homes, Shelters | gal/cap/day | 0.5 | 0.5-5 | 5-40 | 40 |
| b. Hospitals | " | 5 | 15 | 25-40 | 40 |
| c. Mass-care | " | 3 | 10 | 15-25 | 25 |
| (Water allowance for other categories to be developed by utility) | | | | | |

TABLE XVI
ESTIMATED WATER ALLOWANCE SCALE TIME-PHASE

| Water use Category and type of Facility or Operation | Water Allowance Scales to be used on or before Estimated Indicated Date | | | |
|--|--|--------------|--------------|----------------|
| | D Day | D + 15 | D + 45 | D + 90 |
| | to D + 14 | to D + 45 | to D + 90 | to D + 1 yr |
| 1. Potable Water | | | | |
| a. Homes | A | B | C | C-D |
| b. Hospitals | A-B | B-C | C | C-D |
| c. Mass-Care Centers | A | B | B-C | C |
| (Scale for other categories to be developed by utility) | | | | |

Water from the distribution system could be served directly, if necessary, from storage facilities, sources of supply, or from transmission pipe lines. Measures should be developed for its use, especially where large lines are in the vicinity of shelters, emergency care centers, or other locations where there may be survivors. Hydrants might be provided with taps to serve the local residents or water tank trucks. The rate of delivery of water can be increased by using manifolds with a number of taps. Measures should be developed to use water that may be held in the distribution system piping. Water could be made available by tapping the line at the low point by using a low lift portable pump, or by dipping through openings in the pipe.

In the distribution system, emergency or permanent interconnections may be made between high-and low-level zones for service of water between these zones by gravity or pumping. Emergency pumps may have to be used to readily supply needed fire and sanitary water from emergency water sources. Distribution storage facilities should be disconnected immediately after the disaster so as to prevent water wastage and later be put into service as needed, to supply the emergency water. In supplying water from the distribution system, the utility should consider methods of rerouting water and the effect on the carrying capacity of the mains by valving off given sections.

In taking water from sources inside or adjacent to the utility area it may be necessary to use auxiliary portable pumps. These should preferably be so valved that suction and discharge can be interchanged. A study should be made in the advance planning to determine the number and size of portable gasoline or diesel engine-driven auxiliary generators and pumping equipment that may be needed for such purposes and their availability in the area. Fire department pumpers may have to be called into service to supply water other than that for fire fighting.

Hauled water will have to be brought in if it is not possible to distribute water to survivors through the piping system. This operation might well be made the responsibility of agencies other than the water utility, so that utility personnel can devote their time to putting the distribution system back into operation as rapidly as possible. Short fire hoses can be used to fill the tank trucks from hydrants. However, for frequent and fast filling of a number of tanks at the same time a riser attachment with manifold can be used. Tank trucks can be used to deliver hauled water by traveling through specified areas, temporarily stopping and supplying water to consumers who bring their own containers; by being stationed at a fixed point near the area of need; or by delivering water to stationery storage tanks or other temporary storage facilities from which the consumers may obtain their water. People may bring tubs, kettles, jugs, bottles, etc. to get the water. Fifty-gallon drums may be carried on semi-trailers, stake trucks or vans and distributed at strategic points, for the dispensing of water to consumers. Railroad tank cars are another means of hauling. Normally, rehauling by tank trucks to the points of need will be necessary.

Before delivering water by tank truck or railroad tank car the tanks should be thoroughly cleaned and disinfected. The cleaning and disinfection

procedures would depend upon the substances which the tanks previously held. The locations of stations and facilities for cleaning and disinfecting tanks and containers should be known to the utility personnel. The water in the tanks and containers should be chlorinated as a minimum to a free residual at points of distribution. Such chlorination is simple and quickly accomplished but in an emergency it may be set aside unless absolutely necessary.

Water in containers can also be distributed from trucks in bottles, milk cartons or other containers; cans, milk cans, and barrels. Such methods, if must be realized, are suitable only for a very limited population for periods of relatively short duration.

Water stations for emergency water distribution, pumping and/or treatment should be planned to supply water to those consumers without water, giving priority considerations to medical care facilities, and mass feeding operations.

Emergency Water Treatment

Under normal conditions a water utility may have no treatment whatsoever, or it may have disinfection facilities only, or there may be facilities for clarification, softening, filtration, and color and odor control as well. Following a nuclear disaster it may be possible to operate without some of these features. The objective for service of potable water is a supply that can be used safely for drinking. For most of the other uses practically any water could be used as long as it does not clog the piping or pumps. Surface sources may be contaminated from radioactive fallout, from sewage or from industrial chemicals. Water mains that have been fractured simultaneously with nearby sanitary sewers can be grossly contaminated and special precautions will be required to disinfect them prior to their being placed back into service. Low or negative pressures in the mains caused by unusual demands from fire fighting, breaks, etc. can result in back siphonage of sewage or industrial waste thus contaminating the water system.

The normally used treatment facilities should be provided with a maximum degree of flexibility. There should be provision for ready conversion of all automated operations and controls to manual operation. After a disaster it is not unlikely that changes will be necessary in the operation of the treatment works. Increased dosages of some chemicals and elimination of other chemicals during emergencies should be included in disaster procedures. Special treatment like increased chlorination must be considered. An addition, there should be provision for by-passing the treatment works. A minimum 30-day chemical supply should be maintained at the treatment plant. The disposal of radioactive waste material, if a radioactive supply is treated, is another important consideration.

The utility should know where sources of chemicals are available in the area. Means should be provided to locate and use equipment, materials and personnel available in the area which are necessary for the provision of emergency treatment.

Mobile treatment facilities are also necessary to provide the maximum flexibility in treating a contaminated supply at any point in the distribution system and for treating emergency auxiliary sources. Emergency mobile water treatment facilities should be maintained including both chlorination and filtration units with coagulation facilities. The mobile units provided should be able to treat water containing radioactive materials. A plan should be prepared to use the mobile equipment to treat water that will be supplied to critical installations and consumers. Stockpiles of chemicals for the mobile units should be maintained.

Many health departments and civil defense agencies have portable chlorinators available for emergency use. In addition various governmental agencies have stockpiled portable water filtration units at strategic sites. Mobile units may prove especially useful in supplying the larger water allowances required for hospitals and mass-care centers. Waterworks personnel should have knowledge of all extra mobile treatment equipment and replacement parts in the area. They should be able to operate this equipment and should make arrangements for its use during emergencies.

The type and degree of treatment that must be given the emergency water source will of necessity rely on the judgment and decisions of the water utility and health department personnel. The crisis will probably not permit time for conventional laboratory analysis as a basis for determining treatment methods. Color, taste, odor, and turbidity of the water together with the sanitary location of the source will need to be evaluated before it can be determined if simple chlorination will suffice or if coagulation settling and filtration will also be required.

The utility under its normal operation should have adequate laboratory monitoring procedures and should establish base lines on water quality levels beyond which predetermined procedures for identification, assessment of hazard and taking of protective measures including treatment are initiated. For emergency use, simple and rapid radiological detection techniques should be available. The chlorine residual test will have to be relied on as a principal measure of water supply safety against disease organisms pending the results of the more time-consuming bacteriological tests. The membrane filter test provides the most rapid method for determining possible bacterial contamination.

Chlorination, in spite of some shortcomings, is the best single protective device against pathogenic organisms. Consideration must be given to the limitations of such treatment. A free available chlorine residual of one mg/l throughout the distribution system will kill or inactivate vegetative bacteria provided that the water supply is low in turbidity. A higher free available chlorine residual will be required to inactivate certain enteric viruses. The maintenance of free available chlorine at the highest possible level throughout the system consistent with palatability requirements is the single measure that will do the most to protect against biological contamination. However, consideration must be given to the length of time chlorine stocks will last before using high residuals in the system.

Numerous studies, tests and calculations have indicated that the biological effects from drinking water that has been contaminated by radioactive fallout, in the first few months postattack, would generally be insignificant compared with the external gamma radiation hazard.

Probably few adults protected by adequate fallout shelters will die from the internal radiation effects due to drinking radioactively contaminated water. This statement does not apply to babies or children whose uptake ratio is different.

However, the operational effectiveness of existing and conventional water treatment plants should be improved to decrease still further the radiation hazard due to the ingestion of contaminated drinking water.

Water that must be taken from stream channels, ditches, or other surface sources, may be highly turbid, contain radioactive material particles and have a very high chlorine demand. In order to reduce this form of contamination an earthen settling basin should be constructed adjacent to the stream, to receive diverted water that could flow by gravity from the stream. The settling action in the basin will permit partial clarification of the water prior to further treatment and pumping to the point of use. Alum added to the water entering the basin would improve the clarification efficiency of the unit. Pump suction from such a basin should be as far as possible above bottom. Figure 20 shows the effective radioactive water decontamination processes.

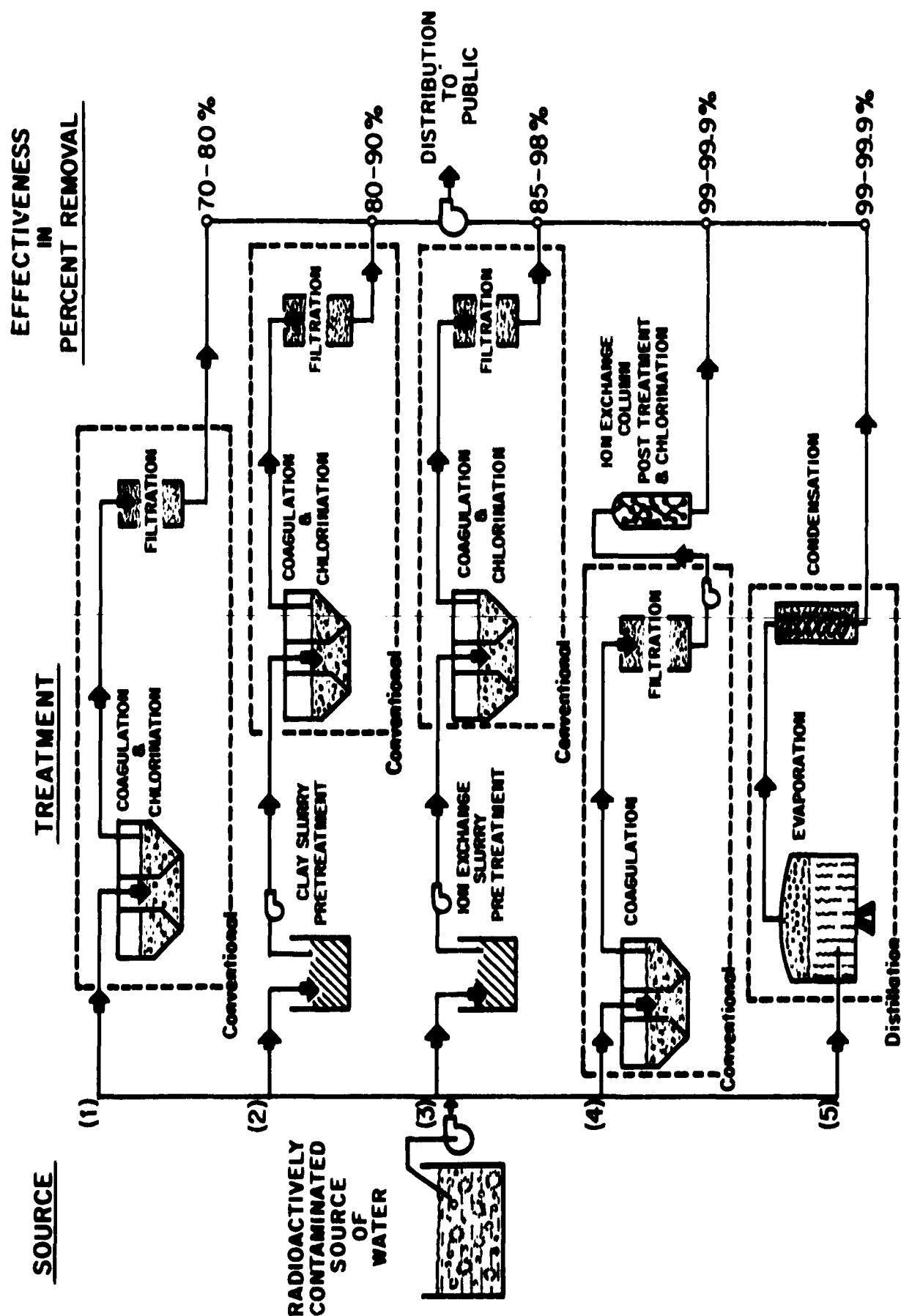
Notification of the public must not be overlooked in the supplying of emergency water. The survivors should be kept informed during all stages of the disaster as to the sources of water and the procedure to follow in order to utilize the available supply. In the immediate postattack period the public must be advised of the water quality in the mains, the means of obtaining a satisfactory water and the need, if any, to conserve or treat water. Statements issued by the utility should be concise and presented so as to eliminate as much anxiety as possible.

Notification of the public may be through radio, TV, sound trucks, etc. As part of the advance planning a survey should be made of all possible means of communication and plans should be prepared for their coordination.

Disaster instructions for the consumers should be issued by the water utility whenever possible in advance of an actual disaster. Typical notices to the consumer might include information on home storage of drinking and sanitary water, water waste prevention, what to do when the water service is interrupted, purification of contaminated or possibly contaminated water and the need and procedure for obtaining information on the water supply following a disaster. Placards and signs could also be prepared in advance to direct the public to water stations.

A major proportion of the postattack survivors will have either covered distribution reservoirs or ground water sources available, and this water if properly handled will be free of radioactive contamination.

Figure 20.-EFFECTIVE RADIOACTIVE WATER DECONTAMINATION PROCESSES *



* Based upon: Leacy, W.J., "Civil Defense Planning", J. Am. WWA, Vol. 55, No. 10, pg. 1220, Oct-1963

REFERENCES

- (1) Lacy, W. J., "Civil Defense Planning" Jour. AWWA, Vol. 55, No. 10 October 1963.
- (2) "Minimum Potable Water Supply Requirements in Civil Defense Emergencies" (TB-11-16), OCDM, October 1958.
(Reprinted in JAWWA, 51:964, August 1959).
- (3) "Operation and Repair of Water Facilities in Civil Defense Emergencies" Office of Civil Defense (TM-13-2) Washington D.C.

CHAPTER VIII

DISASTER PLAN

INTRODUCTION

In the preceding chapters of this manual a detailed review has been made of the effects of a nuclear disaster and the measures which can be taken by a water utility to minimize these effects and to facilitate recovery. Such measures require action prior to the disaster. The extent of preparedness of a utility will determine to a major degree the speed with which recovery takes place. It, therefore, follows that each utility needs to develop a functional, working nuclear disaster plan that will provide both for a realistic self-evaluation of the utility's strengths and weaknesses and for the organization, personnel, equipment and materials to carry out the necessary action to bring the utility up to a reasonable preparedness level.

This chapter contains the information needed for the preparation of a disaster plan and discusses how to incorporate the preceding chapters into an effective plan of operation. It must be emphasized that each utility has its own characteristics and problems which differ from those of others. Each disaster plan must therefore be made to allow for the peculiarities of the specific utility.

The disaster plan should cover surveys, assessments and actions to take place prior to an attack and actions to take place during the alert and following the attack. The aim of the disaster plan is to provide during the postattack period for the most effective utilization of the resources available to the utility. This can be done by providing an effective plan, trained personnel and sufficient emergency equipment and material.

ADVANCE PREPARATION

Disaster Organization

The preparation and organization of the disaster plan should be made the responsibility of competent personnel who should guide the utility in making necessary studies and developing a preparedness program. Full-time employees under a disaster coordinator should be used in the larger utilities. The formation of an advisory committee of personnel having special knowledge and skills is advisable.

The utility's operational disaster organization should include all regular personnel and emergency auxiliary personnel. The disaster organization staff is designated with alternates and replacements at least three deep in the key positions. Responsibilities and channels of command and liaison

should be clearly defined. Some water systems can be divided into districts or zones for independent action with separate personnel assigned to each zone. Emergency teams may also be designated.

The disaster organization will operate out of control centers following the attack. Control stations for the postattack operations should be designated and equipped. They will include command post and alternate, control points and alternates, assembly areas and reporting centers.

Mutual Aid

Mutual aid and joint venture agreements will provide for the exchange of assignment during emergencies of personnel, equipment and materials. Such agreements should also call for coordination of communications, training, reconnaissance and assessment, inventorying, standardization of material and equipment. Effective mutual aid includes agreements not only with other utilities, but with electric, gas and telephone utilities; civil defense, health, fire and police departments, and other interested agencies. Coordination is especially needed with the local civil defense agency and with other utilities in the community and in the geographical area. In the mutual aid agreements responsibilities should be defined and assigned. The agreements should clearly designate the area, organizations, personnel, equipment, materials, facilities and services to be included. Legal questions, such as the transferring of equipment, materials and facilities and the problems that might arise from use of personnel in the crossing of state and county lines, should be studied and resolved. Interconnections with adjacent systems should be planned for and provided.

For mutual aid to be effective, utilities over wide areas should be included in the cooperative agreements. The area of cooperation should be large enough so that it will ensure that some assistance will be available even in an extremely widespread and destructive attack. An area-wide inventory should be made of materials, equipment, chemicals and personnel available to all of the agencies cooperating in the agreements. Emergency equipment and materials should be standardized. Agreements should provide for a comprehensive system of area-wide communication facilities and monitoring services; damage survey and assessment; personnel training; integration of the emergency plan with suppliers of materials, components and services; and the keeping of other agencies advised of current conditions, utility emergency personnel and location of pertinent records. Mutual aid agreements are also advised to be made with adjacent water utilities, and interconnections with such utilities are often provided. In addition, agreements can call for the maintenance or planning of interconnections with industrial or other private auxiliary supplies under proper supervision. The relation of the state disaster planning to the area and local planning should also be considered by the utility.

Security

The water utility should determine the degree of physical security protection needed and provide security procedures. Security measures will include

the use of weapons, reporting of incidents, safeguarding classified material, critical area protection, and employee security training.

Stockpile Inventories

An adequate reserve of materials, parts, supplies and equipment required for a nuclear disaster should be maintained in the amounts to satisfy the normal 30-day requirements. The amount stocked will depend upon the individual water utility, conditions upon which it operates, and upon the probable amount available from other water utilities through mutual aid, to determine additional needs for emergencies. Mutual aid agencies should cooperate in stockpiling needed equipment and supplies and in determining the best storage locations. Warehouses containing these items should be located at well dispersed points. The stockpiles essential for disaster operation and recovery should be reasonably protected.

Stockpiled equipment might include lightweight quick-coupling pipe, couplings, fittings, special adapters, gate valves, pipe locators, portable pumps, generator sets, lighting equipment, portable water treatment units and mobile chlorinators, air compressor units, fire hose, chemicals, fuel and laboratory supplies.

Records

The maintenance of essential records and inventories are an important part of preparedness. It should first be determined which records are essential and need protection. The essential records kept should include those on personnel, emergency sources, stockpiled items, critical consumers, emergency requirements, emergency procedures, maps, emergency plans, etc. The adequacy of existing records should be investigated and improvements made where necessary. Records can be protected by duplication and dispersion. Office personnel may be directed to protect working records in the event of an alert. Copies of all records should be readily available to key emergency personnel. Duplicate copies should be available at mobilization centers and at other sites which are considered relatively safe from a major disaster in the utility area. All parties to mutual aid agreements should be kept informed of these sites. All important records should be kept up-to-date. The records should be easily read with standard symbols and terms used. It is especially important that valve crews and service trucks be provided with maps and current records showing location and condition of the mains and valves.

The essential inventory records should include information on:

- 1) Emergency utility and auxiliary personnel - names, addresses, telephone numbers, disaster responsibilities, skills, availability of transportation, etc.

- 2) Potential emergency sources - location, capacity, probable potability and safety, need for treatment and pumping reliability of continued operation during emergencies, estimate of equipment and supplies likely to be needed in their use, means for making connection, means for locating persons responsible for these sources, and signed agreement by owner for public use of supply in emergency.
- 3) Amounts, types and locations of emergency stockpiled equipment, materials, supplies, and chemicals (including repair items), both belonging to the utility and that available in the area.
- 4) Vehicles and equipment for hauling emergency supplies and emergency water.
- 5) Treatment equipment such as auxiliary chlorinators available in the community.
- 6) Critical consumers with their priorities and their water quantity and quality requirements.
- 7) Estimates of requirements to meet severe emergencies.

Vulnerability Assessment

A vulnerability assessment, as stated in Chapter III, is needed to find where there is likely to be failure or weakening following a nuclear disaster and then, considering priorities, to determine the measures needed to bring the items reviewed up to a reasonable protection level. The studies should not only be on the water system, but on power supply, communications, equipment, material, supplies, personnel, security, and emergency procedures. Studies should be based upon probable response to blast, thermal and ionizing effects. The nature and extent of damage to be expected is estimated as thoroughly as possible. Determination can be made of the type and degree of damage under various conditions and of the repair methods and equipment, materials and personnel needed to initiate recovery and restoration. The evaluation should indicate priorities for repair of the system and alternate provisions in case of loss or severe damage. The studies will show what operations will be affected and this in turn will indicate the need for provision of possible methods of repair and improvisation needed to restore that particular operation as well as the equipment and materials needed.

Hardening includes any measures taken to strengthen a system so that the vital parts will resist the damaging effects of attack. Using the information assembled from the vulnerability studies, decisions can be made as to what units should be hardened and to what extent. The criterion will be that enough of the system survive the attack to supply the water needed. Knowing the condition and vulnerability of the system pre-attack and the level of effects to which it is assumed each part thereof will be subjected, the post-attack condition of the system can be predicted and methods developed for recovery.

Goals with reasonable achievement dates should be formulated using the findings of the vulnerability assessment. Vulnerability reduction measures should be put into effect so as to provide for continuity of operations during an emergency.

General vulnerability reduction (hardening) methods available include:

- 1) Provision of personnel shelters adequate in construction, location, size and number.
- 2) High standards of construction.
- 3) An optimum preventive maintenance and testing program.
- 4) Duplication and separation of vital works.
- 5) Minimizing dependence on power and pumping.
- 6) Provision for more than one source and/or transmission line.
- 7) An active cross-connection control program.
- 8) Adequate valving to prevent extensive areas being deprived of water.
- 9) Maintenance of emergency or permanent interconnections within and outside of system.
- 10) Distribution storage facilities which can be disconnected immediately to prevent water waste and later be put into service as needed.
- 11) Flexibility in operation of treatment works.
- 12) Maintenance of adequate chemical supplies.
- 13) Maintenance of emergency mobile water treatment equipment.
- 14) Provision of dual power sources, on-site storage of fuel and auxiliary power units, remote and/or automated controls, and ready conversion of automatic controls to manual operation.
- 15) Provision of portable pumps with fuel-operated units.
- 16) Provisions at major pumping plants of more than one incoming and discharge lines and plan for shutdown of pumping plants during extreme emergency so as to conserve water.

- 17) Provision of security measures for facilities, material and personnel.
- 18) Training of regular and auxiliary personnel in emergency operations and procedures.
- 19) Conducting emergency operations exercises periodically.

Water Supply and Distribution

Under normal conditions all the water in the utility system is expected to meet domestic water standards, be safe, attractive, clear, colorless, cool, contain no objectionable taste or minerals and be supplied in quantities sufficient to meet all needs during periods of maximum demand. The utility under its normal operation will investigate these conditions and determine what, if anything, is necessary to bring the water quality and quantity up to these standards. Under both normal and emergency conditions the raw and treated water should be monitored for radiological, chemical and biological quality and baselines established on water quality levels beyond which pre-determined procedures of identification, assessment of hazard and taking of preventive measures are initiated.

Under severe damage conditions, the quality and quantity requirements described above cannot be expected to be met at all times. The utility is advised to follow Supply Procedures reviewed in Chapter VII to make an advance determination of emergency water needs for various categories of use such as potable, sanitary, decontamination, fire fighting, industrial and agricultural water. Consideration must be given to water allowances, rationing, priorities and time-phasing of estimated water requirements. Critical water users should be inventoried and their quantity and quality requirements determined. Requirements will change with changing conditions. The minimum supplies, equipment, manpower and organization arrangements needed to meet the water requirements should be determined. Investigations should be made of supply procedures, emergency treatment, use of mobile treatment and pumping facilities and emergency methods of distribution of water. The vulnerability assessment should be used to determine measures needed to protect water quality and quantity. As potable water may not be available immediately, consumers should be encouraged to store water sufficient for at least 14 days in fallout shelters. During the period immediately after the attack an acceptable potable water may be that water which has been determined as not being contaminated with sewage or other highly toxic material and which has received a very minimum treatment. Watershed damage and its effect on water quality must also be considered along with damage in the distribution system.

Under fallout conditions radioactive decontamination may be necessary if the supply or the distribution facilities are not properly protected. The need for monitoring the supply has already been reviewed. The utility should investigate and make available fast and reliable means of determining the radioactivity level of the area. The utility should investigate and provide the means to protect the supply against fallout and to treat the supply for removal of radioactive material.

As the normal sources of supply or the distribution facilities may be unavailable or unusable after a nuclear disaster, investigations should be made by the utility to locate and inventory emergency sources of supply. Plans should be established to obtain and use emergency water from the utility system, auxiliary sources inside or outside the utility areas and from the hauling of water as reviewed in Chapter VII. Consideration should be given to amount of water available, damage potential, pumping and power requirements, need for auxiliary pumping facilities or treatment, and equipment, material, personnel and transportation requirements. Consideration must be given to rerouting of water and to isolation of parts of the system.

In providing emergency water, the utility must also consider the availability of materials and supplies required for emergency disinfection, and a procedure should be established for obtaining and using such items. In addition, plans should include the service of essential water through the provision of emergency water distribution, treatment and/or pumping stations.

Communications

Adequate communications will significantly increase the rate of recovery following a nuclear attack. During the pre-attack period a study should be made of the existing communication facilities, the improvements needed to bring them up to an acceptable level, and then the necessary corrections should be made. Both radio and telephone facilities should be provided and integrated into the emergency operation plan. Facilities should be provided both in fixed installations and mobile units. The mobile units should be able to communicate with each other when the base station is not operating. Facilities should be provided for intercommunication or monitoring of nearby utilities. Backup personnel for operation of the communications equipment are essential. The fixed communication equipment and facilities should be installed in sites that are adequate as personnel shelters. Standby power and on-site storage of fuel and generators are needed at command and control points.

To prevent public panic and confusion following a disaster, provision should be made to issue statements frequently and clearly through a utility public information officer and alternate. Procedures for release of information should be formulated. A survey of all possible means of communication and a plan for coordinating them should be made in the advance planning. In addition, relations with the press and radio should be established so that there is a mutual understanding of the problems involved and agreement on methods to be followed. Means should be prepared to disseminate information on water quality in the mains, the availability of satisfactory water and the need, if any, to conserve or treat water. The public may be notified by radio, TV, telephones, sound trucks, etc. News releases or canned announcements should be prepared in advance for emergency conditions that are likely to develop and should include information on water rationing, home storage of drinking and sanitary water, water waste prevention, emergency water distribution points and emergency purification and disinfection by individuals. Lists should be prepared of essential industrial users who should be notified

of a change in water quality that would affect their product. Placards and signs can be prepared in advance to direct the public to predesignated locations where water is made available.

Personnel Protection

The establishment of shelters and a mobilization program whereby key employees will be in the shelters at the time of attack is of utmost importance. Ionizing radiation will injure personnel who are not adequately sheltered during the initial attack and for an extended period thereafter. Injury and death will also result from blast overpressure when insufficient protection is provided.

A shelter survey should be made to determine the number and location of shelters needed and then a program for their establishment instituted. Shelters should be provided in locations that all intended occupants can reach within a minimum period of time and near where the emergency work would have to be done. The provision of shelters in the immediate vicinity of critical waterworks facilities which are manned with operators at all times will facilitate the mobilization of the on-duty operating personnel if the warning period is sufficient for such personnel to take shelter before the attack. It must be recognized that personnel not sheltered at time of attack in the vicinity of the location where they will be needed in the early postattack period will be available only if they survive the initial effects and can get to their assigned location without exposure to excessive radiation. Each essential operating unit or element should have a shelter. The determination should be made of the best location for shelters in existing structures and means for improving shelter protection in these structures put into effect. Serious consideration should be given to provision of shelters in new structures. Every effort should be made to keep the radiation dose receivable within the shelter as low as possible in order to permit personnel to enter contaminated work areas earlier and stay longer.

Sheltering of families of personnel should be considered so that there will be more likelihood of the personnel reporting to the assigned shelters when the alert is sounded. A family protection program is very advisable.

Equipment needed for the shelters should be determined and provided. Shelters should have essential survival items that will allow reasonable living conditions for at least 14 days. Adequate equipment and supplies to maintain employees in good physical and mental condition should be provided. Consideration must be given inside the shelter to space, ventilation, water, food, sanitary facilities, personal hygiene, communications equipment, radiation monitoring equipment, medical supplies, lighting, etc. Means of communication with command and control posts must be available to implement decisions, maintain continuity of authority and to assure organized action.

Means should exist for mobilizing the full complement of men in accordance with the emergency plan should an alert be sounded or a surprise attack occur. A portion of the waterworks staff is normally maintained in a state

of readiness to respond when emergency conditions demand, but even these men are generally occupied on low priority routine work until called. The mobilization plan must be flexible enough to provide for the various conditions including the assembly of off-duty personnel. Personnel should be well versed in procedures for carrying out the mobilization plan under various circumstances so as to reduce the time needed to reach assigned shelters.

Personnel should not only be trained to be thoroughly familiar with radiological protection, but should also be trained on basic civil defense subjects including first aid.

Radiological Monitoring and Training

Advance measures to minimize the disrupting effect of a nuclear attack must include the training of personnel to live and survive in a radioactive environment. An important part of this training is the use of monitoring equipment to determine radiation levels. Raw and treated water supplies should be monitored under normal utility operation. Procedures for sampling, analyzing and reporting results under emergency conditions should be established. The utility should investigate and provide the needed monitoring equipment and then train their employees in the use of this equipment. Both sensitive laboratory equipment and portable survey meters should be provided. All personnel should be familiar with the operation of the portable meters. Equipment, procedures and laboratory staff training should be developed so that a maximum number of samples can be analyzed quickly and efficiently. Rapid field tests should be made available to selected personnel. Each employee should have a dosimeter and keep accumulated dose records to show the level of radiation exposure. Monitoring equipment should be provided at each mobilization area or shelter. The disaster plan should call for the reporting of radiological monitoring results to control centers. Provision for servicing of monitoring equipment so as to keep them in proper order is essential.

Training of personnel, both regular and auxiliary, is needed in radiation exposure hazards and in the protective procedures and precautions to be taken when working in the presence of radioactivity. This training may be part of the Mutual Aid Program. Personnel should understand what radiation is, what it can and can't do, and how best to protect themselves from it. They should be thoroughly trained on the action they must take before and after a nuclear disaster. Provision may be made to protect equipment and materials during the alert by placing them under suitable cover. Personnel should know where the shelters are located and what the characteristics are of a good improvised shelter that could be used if designated areas are not available. They should have the equipment and knowledge for determining when a shelter can be left and the length of time that one can safely work in a radioactive environment. The employee must be thoroughly trained to understand and respect radiation intensity, total exposure dose, accumulated dose, dose rate and stay time. Control is needed of the movement of personnel from shelters to perform essential work. Personnel should be familiar with and be provided with the means for removing radioactive contamination from water supplies, facilities and

areas. They should be familiar with radiation standards for water and air and should know at what radiation level the supplying of contaminated water should be stopped or the consumers adequately warned. They should know which sources or facilities are likely to become contaminated and which are not. Personnel should be able to determine whether a particular facility or area needs or should be decontaminated and when, how and by how many persons the work should be done. They should know how to safely dispose of contaminated water used for decontamination purposes. They should be informed on posting of contaminated facilities and areas.

Decontamination operations outside the shelter should receive special consideration. When the decision is made to recover a contaminated installation, the first step is to establish a suitable staging area from which the recovery operation can be launched. Next, the vital area is surveyed with regard to radiological contamination and physical condition, the site is prepared for recovery and proposed reclamation measures are tested for effectiveness. The site is then prepared by removing debris and obstructions, checking adequacy of water supply, drainage channels, etc. Boundaries of vital areas, access routes, and staging areas are clearly marked to prevent entrance into hazardous areas or the bringing of significant amount of contamination into clean areas. After the operation is finished and the radioactive area is left, contaminated clothing is removed before returning to the clean or relatively clean areas.

Personnel should be trained and retrained in use of equipment and should be provided with routine test exercises to perfect emergency procedures.

POSTATTACK OPERATION

An effective postattack operation plan will provide for a priority listing of immediate actions to be taken at each level to initiate recovery. The plan should be time-phased by designating action to be taken after certain assumed periods.

The plan will provide for the activation of the disaster organization including all regular and auxiliary personnel. Procedures must be established for mobilizing the available disaster staffs. This would involve means of determining their postattack availability or the availability of the designated alternates and how to use those that are mobilized. Use of communications and personnel records would be very important during the mobilization period. The designated command posts, control locations and assembly areas with alternates will be staffed and put into operation as soon as the alert sounds. The defined channels of command and liaison will also be put into effect at the same time.

Operations during the period that personnel must remain in their shelters should be included in the disaster plan. At this time the communications equipment will be of special importance. Information can be received on status of attack, surviving personnel, radiation conditions, and some preliminary information on the condition of the water system may be available through

electronic sensing equipment or other means. Liaison with other civil defense units should be one of the first objectives. In the shelters some possible sources of information would be CD control center, intercommunications with sheltered waterworks personnel, automatic controls and electronic sensing equipment, reports from other CD personnel, weather reports, aerial monitoring reports, etc. Using the information available, planning can begin for the operations to take place when it will be safe to leave the shelters for short periods.

One of the first tasks for the utility will be the assessment of damage and evaluation of surviving facilities and the surviving community. The utility will have to determine what the postattack water needs are, the facilities that can be utilized, and the most effective way to resume operation in the available time. When it is first determined that it is safe to leave the shelters, there will be a probing operation to obtain further information and improve the assessment of damage. Information would be gained during a short period sufficient to permit decisions as to action priority and personnel, equipment and material needs. The weaknesses found in the vulnerability studies would be the first place to look for damage. Evaluation must be made of the capability of the surviving system. Applicable records should be used. Assessment and evaluation information would be recorded and disseminated to the various control centers as needed. Initial recovery efforts would be limited to individual and small group actions, pending assessment of damage and evaluation of radioactivity hazards to personnel. When central control is resumed, realistic recovery actions can be ordered, based in part on data determined in the pre-attack analysis of the system, during which time priorities for repair and recovery actions should have been determined.

Procedures for the operation of surviving facilities must be established. This would include control of water loss, conservation of quality water by isolation of damaged portions of the system and by isolation of storage facilities. Contaminated facilities must also be isolated. Emergency source, treatment, storage and distribution facilities would be activated for the service of emergency water. Essential water monitoring services, with emphasis on radiation and bacteriological monitoring, would now be needed. The easily recoverable system facilities having high priority should be reactivated as soon as possible. Improvised operating and repair methods would be put into effect at this time. Decontamination measures would be used where necessary.

Procedures for the service of a temporary water supply are of vital importance. The location of water needs as well as the availability of water can best be determined through joint effort with other civil defense disciplines such as fire control, decontamination, and public health units. The determination of location, quantity and quality requirements should be time-phased. Water rationing should be instituted if necessary. The utility must be ready to participate in the establishment and operation of water stations in cooperation with other agencies. Criteria should be established for determination of service areas that are to be supplied with water for survival by each of the various methods, such as piped water, hauled water or by evacuation

of survivors to areas having water. Means must be determined for making available essential water from the utility system, and from auxiliary supplies inside or outside the utility area. The more protected sources should be used wherever possible. Records pertaining to alternate supplies and critical water needs are of importance in this operation. Emergency water treatment equipment should be available and used where needed. Of special importance is a procedure for notification of the public of the location and quality of emergency water.

Procedures must also include those necessary for the recovery of the system and restoration of operations. This would include the estimation of manpower, equipment, and material needs to recover a sufficient system to provide at least 10 gallons/capita/day in the early postattack recovery period. The emergency repair program would be expanded as required. Disinfection of distribution systems would be accomplished where necessary. Operational procedures for recovered facilities would be established.

The operational disaster plan, for maximum effectiveness during the postattack period, should be maintained in a state of readiness with a well publicized program, thoroughly trained personnel, and a continuing program of testing, evaluation and revision.

Water source contamination by fallout would be a secondary problem in the postattack environment: rather, water distribution itself would be a major problem, especially for survivors in targeted cities.

DISASTER PLAN CHECK LIST

The following check list will aid in establishing a disaster plan.

ADVANCE PREPARATION

Form Disaster Organization

- 1) Appoint responsible personnel for development, training and research.
- 2) Appoint advisory committee to these personnel.
- 3) Designate disaster organization staff and teams.
 - a) Designate alternates.
 - b) Define responsibilities, channels of command and liaison.
- 4) Designate and equip stations for postattack operations.
 - a) Command post and alternate.
 - b) Control points and alternates.
 - c) Assembly areas and reporting centers.

Initiate Mutual Aid Agreements

- 1) Provide agreements with related utility, service and civil defense agencies.
- 2) Define and assign responsibilities.
- 3) Provide for exchange or assignment of personnel, equipment and materials.
- 4) Provide for coordination of communication, training, reconnaissance and assessment, inventorying, standardization, etc.
- 5) Consider legal problems.
- 6) Plan and provide interconnections with adjacent systems.

Establish Security Protective Measures

- 1) Determine degree of physical security protection needed.
- 2) Provide security procedures.

Establish Inventories (Stockpiles) and Records

- 1) Stockpile essential equipment, material and supplies for recovery at dispersed stations.
- 2) Provide records which will facilitate recovery.
 - a) Maps and engineering plans.
 - b) Personnel, regular and auxiliary.
 - c) Emergency sources of supply, availability, and means of using.
 - d) Stockpile items.
 - e) Emergency operating methods, and procedures.
- 3) Keep records readily available at all levels of operation.
- 4) Keep mutual aid parties informed of content and location of records.
- 5) Maintain records up-to-date.
- 6) Protect all essential records.

Assess Vulnerability and Initiate Hardening Measures

- 1) Develop vulnerability assessment procedures.
 - a) Predict effect of fallout, thermal radiation and blast under assumed conditions.
- 2) Assess vulnerability of:
 - a) Source, transmission, treatment, distribution and storage facilities.
 - b) Equipment, material and supplies.
 - c) Personnel.
 - d) Power supply.
 - e) Communications.
 - f) Emergency procedures.
- 3) Using results of vulnerability assessment determine:
 - a) Probable postattack condition of system for effects at various levels.
 - b) Repair methods and equipment, materials and personnel needed to initiate recovery and restoration.
 - c) Priorities.
 - d) Alternate courses of action.
- 4) Determine vulnerability reduction measures.
- 5) Formulate program for hardening with reasonable achievement dates.

Establish Water Supply and Distribution Requirements

- 1) For normal and emergency conditions:
 - a) Monitor supply for radiological, chemical and biological quality.
 - b) Establish baselines on water quality levels.
- 2) For emergency conditions:
 - a) Determine water needs for potable, sanitary, decontamination, fire fighting, industrial, and agricultural water.
 - b) Prepare guidelines for water allowances, priorities, rationing and time-phasing of estimated water requirements.
 - c) Determine guidelines for minimum supplies, equipment, manpower and organization to meet water requirements.
 - d) Establish procedures and prepare for emergency treatment, pumping, and distribution of water.
 - (1) Provide for both fixed and mobile equipment.
 - (2) Establish improvised operation within utility system.
 - (3) Provide for stations for service of emergency water.
 - e) Locate, inventory, and prepare plan for use of potential emergency water sources.
 - (1) Utility system (improvised operation under emergency conditions).
 - (2) Auxiliary sources (utility, industrial, private and other supplies).
 - (3) Distant sources (hailed, emergency lines, etc.).

Provide Communications

- 1) Study and coordinate all possible means of communication.
- 2) Bring existing facilities up to an acceptable level.
 - a) Provide fixed and mobile units.
 - b) Provide communication between all critical locations.
 - c) Provide standby power and on-site storage of fuel and generators at command and control points.
- 3) Provide trained communications personnel.
- 4) Prepare procedures for release of information to the public.
 - a) Designate personnel to be in charge of release of information.
 - b) Establish relations with press and radio.
 - c) Establish procedures for use of loud-speakers, leaflets.
 - d) Prepare releases in advance for emergency conditions likely to develop.
 - e) Prepare emergency placards and signs in advance.

Establish Personnel Protection

- 1) Establish Shelter Program.
 - a) Determine number and location of shelters needed.
 - b) Determine effectiveness of existing structures as shelters.
 - c) Provide shelters for personnel at each essential operating unit.
 - d) Harden existing structures as needed.
 - e) Provide shelters in new structures.
 - f) Establish family shelter program.
 - g) Provide communication with command and control point.
 - h) Provide adequate space, equipment, supplies, facilities in each shelter.
 - i) Provide for assembly of emergency utility and auxiliary personnel in shelters.
- 2) Give personnel civil defense personal survival training.

Provide Radiological Monitoring and Training

- 1) Provide monitoring equipment at dispersed locations.
 - a) Establish procedures for monitoring radiation in shelters and work areas.
 - b) Establish procedures for sampling water supply, analyzing and reporting results under emergency conditions of radiological fallout.
 - c) Provide dosimeters and establish methods for keeping accumulated dose records.
 - d) Develop lab to run samples as quickly and efficiently as possible.
 - e) Provide for reporting of radiological monitoring results to control centers.
 - f) Provide for servicing of monitoring equipment.
- 2) Train regular and auxiliary personnel in radiological protection.
 - a) Use of monitoring equipment.
 - b) Radiation guide lines.
 - c) Guide lines for decontamination procedures.
 - d) Guide lines for time and stay-time.
 - e) Maintenance and protection of radiological equipment.
- 3) Provide routine test exercises to familiarize personnel with emergency procedures.

PLAN POSTATTACK OPERATION

Provide for time-phased procedures to:

- 1) Activate disaster organization.
- 2) Mobilize available disaster staff.
- 3) Place into operation procedures for protection of personnel.
- 4) Initiate liaison with other utility units and mutual aid organizations.
- 5) Make reconnaissance of surviving facilities and assessment of damage.
- 6) Determine priority of actions.
- 7) Decontaminate where necessary.
- 8) Initiate procedures for operation surviving facilities.
 - a) Water conservation.
 - b) Isolate damaged facilities.

REFERENCES

- (1) "Civil Defense and Disaster Relief Planning" Division of Defense and Disaster Relief. Executive Department Texas state.
- (2) "Handbook for Radiological Monitors" Office of Civil Defense, FG-E-5.9 April 1963, Washington D.C.

APPENDIX A

FACTS ON RADIATION AND FALLOUT

This is appended as a separate attachment to this report.

APPENDIX B

GLOSSARY

ABSORPTION: The reduction of radiation intensity as a result of the transfer of energy from the radiation to a substance through which it passes.

AIR BURST: The explosion of a nuclear weapon at such a height that the expanding ball of fire does not touch the earth's surface. There is very little early fallout from such a detonation.

ALPHA PARTICLE: A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of four units and electric charge of two positive units. See Radioactivity.

ATOMIC BOMB (OR WEAPON): A term sometimes applied to nuclear weapon utilizing fission energy only. See Fission, Nuclear Weapon.

ATOMIC CLOUD: See Radioactive Cloud.

ATTENUATION: Decrease in intensity of a signal, beam, or wave as a result of absorption of energy and a scattering out of path of detector, but not including the reduction due to geometric spreading; i.e. the inverse square of distance effect.

BACKGROUND RADIATION: A term used to describe the natural radiation of the earth and its atmosphere. It consists of cosmic radiation and radioactivity in the earth, air, and water. The main sources of background radiation are potassium-40, thorium, uranium, and their decay products, including radium, and cosmic rays.

BARRIER SHIELDING: Shielding accomplished by interposing a physical barrier between a given point and radiation source.

BETA PARTICLE: A high-speed electron emitted spontaneously from the nuclei of certain radioactive elements. Most of the fission fragments from nuclear weapons emit beta particles.

BLAST WAVE: A pulse of air in which the pressure increases sharply at the front, accompanied by winds, propagated continuously from an explosion. See Shock Wave.

CIVIL DEFENSE: Civil Defense is the science and technology of advanced preparedness to war problems, analyzing the problems to determine the relative risks of specific actions, developing plans, hardening facilities, acquiring or stockpiling resources of supplies and tools, and training people in survival knowledge and skills.

CONFLAGRATION: A big fire caused by a joining of a good number of scattered fires originated by ignition of many combustible materials through thermal radiation.

CONTAMINATION: A deposit of radioactive material in any place where it is not desired. the deposit is the CONTAMINANT.

COUNTERMEASURE: All preparedness measures taken to act against destruction or disaster.

CURIE: The curie is a measure of the activity or strength of a sample of radioactive material. It is the quantity of any radioactive species in which 3.700×10^{10} nuclear disintegrations occur per second. Because of the large size of this unit, the microcurie (one millionth of a curie or 10^{-6} curie) and the picocurie (micromicrocurie or 10^{-12}) are more commonly used.

DECAY (OR RADIOACTIVE DECAY): The decrease in activity of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation.

DECONTAMINATION: The removal of unwanted radioactive contaminant from a material, e.g., water, air, or from surfaces of objects of interest, e.g. buildings, streets.

DELAYED (WORLD-WIDE) FALLOUT: Small radioactive contaminated particles which ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the earth, mainly by rain and snow, over extended periods ranging from months to years.

DIRTY WEAPON: One which produces a larger amount of radioactive residues than a "normal" weapon of the same yield.

DISTANCE SHIELDING: See Geometry Shielding.

DOSE: A quantity of ionizing radiation. The term dose is often used in the sense of exposure dose, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air.

DOSE RATE: The amount of ionizing (or nuclear) radiation to which an individual would be exposed per unit of time. It is usually expressed as roentgens per hour or in submultiples of these units, such as milliroentgens per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area.

DOSIMETER: An instrument for measuring and registering total accumulated exposure to ionizing radiation.

DYNAMIC PRESSURE: The air pressure which results from the mass air flow (or wind) behind the shock front of a blast wave.

EARLY (LOCAL) FALLOUT: The radioactive contaminated particles which reach the earth within 24 hours after a nuclear explosion.

ELEMENT: One of the distinct, basic varieties of matter occurring in nature which, individually or in combination, compose substances of all kinds. Approximately ninety different elements are known to exist in nature and several others, including neptunium and plutonium, have been obtained as a result of nuclear reactions with these elements.

ENERGY: Capacity for performing work.

EXPOSURE CONTROL: Procedures taken to keep radiation exposures of individuals or groups from exceeding a recommended level, such as keeping outside missions as short as possible.

EXPOSURE DOSE: See Dose

EXTERNAL RADIATION: Exposure to ionizing radiations coming from a source outside the body.

FALLOUT: The process or phenomenon of the fall back to the earth's surface of particles contaminated with radioactive material from a nuclear weapon. The term is also applied in a collective sense to the contaminated particulate matter itself.

FALLOUT MONITORING STATION: A designated facility such as a fire station, police or public works building, or a community shelter which has a protection factor of at least 100 and relatively reliable communications. It may be established with a minimum of two trained radiological monitors but as promptly as feasible the number should be increased to four.

FALLOUT PATTERN: Characteristics of the process or phenomenon of the fall back of radioactive contaminated particles from a nuclear explosion to the earth's surface.

FALLOUT MODEL: A predicted specimen of dose-rate contour for early fallout at specified time period after a nuclear explosion for an assumed yield, type of burst, and meteorological condition.

FIREBALL: The luminous sphere of hot gases which form a few millionth of a second after a nuclear (or atomic) explosion as the result of the absorption by the surrounding medium of the thermal x-rays emitted by the extremely hot (several tens of millions degrees) weapon residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves (radiation front).

FIRE STORM: Stationary mass fire, generating strong, in-rushing winds from all sides; the winds keep the fire from spreading while adding fresh oxygen to increase their intensity.

FISSION: The nuclear process whereby the nucleus of a heavy element splits into two nuclei of lighter elements and releases a substantial amount of energy. The most important fissionable materials are uranium-235 and plutonium-239. This process provides the energy for the atomic bomb and nuclear reactors.

FISSION FRACTION: The fraction (or percentage) of the total yield of a nuclear weapon which is due to fission. For thermonuclear weapons the average value of the fission fraction is about 50 percent.

FISSION PRODUCTS: A general term for the complex mixture of substances produced as a result of nuclear fission. The complex mixture of fission products contains about 200 different isotopes of 36 elements.

FLAME BURN: Indirect (or secondary) skin burn that would accompany (or are caused by) any large fire no matter what its origin.

FLASH BURN: A burn caused by excessive exposure (of bare skin) to thermal radiation. See Thermal Radiation.

FRACTIONATION: Any one of several processes, apart from radioactive decay, which results in change in the composition of the radioactive weapon debris.

FUSION: The process whereby the nuclei of two light elements combine to form the nucleus of a heavier element with the release of substantial amounts of energy. It occurs most readily with hydrogen and its isotopes, and it provides the energy for the hydrogen or thermonuclear bomb.

GAMMA RAY: A penetrating radiation of high energy emitted by a radioactive nucleus. It is of the same general nature as X-rays and ordinary light, though more energetic. Gamma rays can penetrate considerable thicknesses of matter.

GEOMETRY SHIELDING: Shielding accomplished by distance from source of radiation.

GROUND ZERO: The point on the surface of land or water vertically below or above the center of a burst of a nuclear (or atomic) weapon; frequently abbreviated to GZ.

HALF-LIFE: The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition.

HALF VALUE THICKNESS: The thickness of a given material which will absorb half the gamma radiation incident upon it. This thickness depends on the nature of the material - it is roughly inversely proportional to its density - and also on the energy of gamma rays.

(H + t) HOUR: t hours after nuclear explosion.

HARDENING: All measures taken to strengthen facilities so that vital parts will resist the damaging effects of attack.

INDUCED RADIOACTIVITY: Radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of unstable (radioactive) nuclei. The activity induced by neutrons from a nuclear (or atomic) explosion in materials containing the elements sodium, manganese, silicon, aluminum or uranium may be significant in some cases.

INITIAL NUCLEAR RADIATION: Nuclear radiation (essentially neutrons and gamma rays) emitted from the fireball and the cloud column during the first minute after a nuclear (or atomic) explosion.

INTENSITY: The energy (of any radiation) incident upon (or flowing through) unit area, perpendicular to the radiation beam in unit time.

INTERNAL RADIATION: The radiation exposure resulting from the deposition of radioactive materials within the body.

IONIZING RADIATION: Electromagnetic radiation (gamma rays or x-rays) or particulate radiation (alpha particles, beta particles, neutrons, etc.) capable of producing ions, i.e., electrically charged particles, directly or indirectly, in its passage through matter.

ISOTOPES: Forms of the same element having identical chemical properties but differing in their atomic masses (due to different numbers of neutrons in their respective nuclei) and in their nuclear properties. Some isotopes are stable and others are radioactive.

KILOTON (KT): A unit of energy of a nuclear (or atomic) explosion which is equivalent to that produced by the explosion of 1 kiloton (1,000 tons) of TNT, i.e., 10^{12} calories or 4.2×10^{19} ergs.

LOCAL FALLOUT: See Early Fallout.

MACH FRONT: The shock front formed by the fusion of the incident and reflected shock fronts from an explosion. The term is generally used with reference to blast wave, propagated in the air, reflected at the surface of the earth. The Mach front is nearly perpendicular to the reflecting surface and presents a slightly convex (forward) front.

MASS THICKNESS: A measure of barrier effect expressed by pounds per square foot of shielding material.

MEGATON: The unit of energy of a nuclear explosion which is equivalent to 1,000,000 tons (or 1,000 kilotons) of TNT, i.e., 10^{15} calories or 4.2×10^{22} ergs.

Mev (million electron volt): Unit used for expressing the energy released in nuclear reaction; it is equivalent to 1.6×10^{-6} erg or 1.6×10^{-13} joule.

MONITOR: An individual trained to measure, record, and report radiation dose and dose rates; provide limited field guidance on radiation hazards associated with operations to which he is assigned; and perform operator's maintenance of radiological instruments.

MONITORING: The procedure or operation of locating and measuring radioactive contamination by means of survey instruments which can detect and measure, as dose rate, ionizing radiations.

NEUTRON: A neutral particle, with no electrical charge, having about the same mass as the proton, and present in all atomic nuclei, except those of ordinary (or light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear explosions.

NUCLEAR RADIATION: Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, capable of producing ions directly or indirectly in its passage through matter including living tissue.

NUCLEUS: The central, positively charged core of the atom which carries essentially all the mass. It consists of neutrons and protons, and the number of protons is the same for all the atomic nuclei (or isotopes) of a given chemical element. The nuclear properties, e.g., radioactive or stable, of an isotope of a given element are determined by both the number of neutrons and number of protons.

OUTSIDE DOSE (OR UNSHELTERED DOSE): The dose outdoors, away from buildings.

OUTSIDE DOSE RATE (OR UNSHELTERED DOSE RATE): The dose rate outdoors, away from buildings.

OVERPRESSURE: The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion.

PEAK OVERPRESSURE: The maximum overpressure value at the blast front.

PROTECTION FACTOR: A factor used to express the relation between the amount of fallout gamma radiation that would be received by a person outside a shelter compared to the amount he would receive if he were in the shelter.

RAD: A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear radiation per gram of the absorbing material or tissue.

RADIATION DOSE: See Dose.

RADIATION EXPOSURE RECORD: The card issued to individuals for recording their personal radiation exposure doses.

RADIATION INJURY: The harmful effects caused by ionizing radiation.

RADIATION SICKNESS: The complex of symptoms characterizing the disease known as radiation sickness, resulting from excessive exposure of the whole (or a large part) of the body to ionizing radiation. The earliest of these symptoms are nausea, vomiting, and diarrhea, which may be followed by loss of hair, hemorrhage, inflammation of mouth and throat, and general loss of energy. In severe cases, where the radiation exposure has been relatively large, death may occur within two to four weeks. Those who survive six weeks after exposure to a single dose of radiation may generally be expected to recover.

RADIOACTIVE CLOUD: An all-inclusive term for the mixture of hot gases, smoke, dust, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon.

RADIOACTIVITY: The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an unstable isotope. As a result of this emission the radioactive isotope is converted into the isotope of a different element which may (or may not) also be radioactive. Ultimately, as a result of one or more stages or radioactive decay, a stable (non-radioactive) end product is formed.

RADIOISOTOPE: An unstable nuclide which emits particulate and/or electromagnetic radiation in the process of transforming to a stable state.

RADIOLOGICAL COUNTERMEASURE: Preparedness measures taken to minimize the effect of nuclear radiation on people and resources.

RADIOLOGICAL DEFENSE: The organized effort, through warning, detection, and preventive and remedial measures, to minimize the effect of nuclear radiation on people and resources.

REDUCTION FACTOR: The reciprocal value of the protection factor.

REM: A unit of biological dose of radiation; the name is derived from the initial letters of the term "rad equivalent man (or mammal)." The radiation dose in rem is equal to the dose in rads multiplied by the RBE of the given radiation (for a specified effect).

RESIDUAL NUCLEAR RADIATION: Nuclear radiation, chiefly beta particles and gamma rays, which persists for some time following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout.

ROENTGEN: A unit of exposure dose of gamma (or X) radiation. It is that exposure which in 0.001293 gram of air will produce ions carrying one electrostatic unit of electricity or charge. This energy absorption amounts to about 88 ergs per gram.

SHELTER: A habitable structure or space stocked with essential provisions and used to protect its occupants from fallout radiation.

SHIELDING: Any material or obstruction which absorbs radiation and thus tends to protect personnel or materials from the effects of a nuclear explosion. A considerable thickness of high density material may be needed for nuclear radiation shielding, especially, in the case of gamma radiation.

SKYSHINE: Radiation, particularly gamma rays from a nuclear explosion, reaching a target from many directions as a result of scattering by the oxygen and nitrogen in the intervening atmosphere.

SHOCK WAVE: A continuously propagated pressure pulse (or wave) in the surrounding medium which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion. A shock wave in air is generally referred to as a blast wave, because it resembles and is accompanied by strong, but transient, winds.

SLANT RANGE: The distance from a given location, usually on the earth's surface, to the point at which the explosion occurred.

STANDARD INTENSITY: The energy (or any radiation) incident upon (or flowing through) unit area, perpendicular to the radiation beam in unit time.

SUBSURFACE BURST: See Underground Burst, Underwater Burst.

SURFACE BURST: The explosion of a nuclear (or atomic) weapon at the surface of the land or water or at a height above the surface less than the radius of the fireball at maximum luminosity. Such a detonation results in the maximum amount of early fallout.

THERMAL RADIATION: Electromagnetic radiation emitted (in two pulses from an air burst) from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infra-red radiations.

THERMONUCLEAR WEAPON: A bomb in which part of the explosive energy is obtained from nuclear fusion reactions. The energy ranges from hundreds of thousands to millions of tons of TNT-equivalent.

TNT EQUIVALENT: A measure of the energy released in the detonation of a nuclear (or atomic) weapon, or in the explosion of fissionable material, expressed in terms of the weight of TNT which would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons or megatons. The basis of the TNT equivalent is that the explosion of 1 ton of TNT releases 10^9 calories of energy.

UNDERGROUND BURST: The explosion of a nuclear (or atomic) weapon with its center more than $5 W^{1/3}$ feet, where W is the explosion yield in kilotons, beneath the surface of the ground.

UNDERWATER BURST: The explosion of a nuclear (or atomic) weapon with its center beneath the surface of the water.

UNIT-TIME REFERENCE DOSE RATE: The ratio of the approximate exposure dose rate (in roentgen/hr) at any time after the explosion to a convenient reference value.

UPPER-AIR-FALLOUT (UF) WIND DATA: The UF wind data are reported by U. S. Weather Bureau upper-air observing stations two to four times daily indicating the direction and distance from ground zero where particles, falling from various levels in a nuclear explosion cloud (10, 20, 40, 60 and 80 thousand feet) are requiring three hours to reach the ground, will land.

WORLD-WIDE FALLOUT: See Delayed Fallout.

YIELD: The total effective energy released in a nuclear (or atomic) explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation, thermal radiation, and shock (and blast) energy, the actual distribution being dependent upon the medium in which the explosion occurs (primarily) and also upon the type of weapon and the time after detonation.

YIELD, FISSION: That portion of the total yield of a nuclear detonation attributable to the fission process. A one-kiloton fission yield detonation results from 1.45×10^{23} fission events.

YIELD, FUSION: That portion of the total yield of a nuclear detonation attributable to the fusion process.

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